2) A summary comparison of the prior data and the new set - are there significant differences? Table or graphic may be useful.

SAMPLING PROGRAM OVERVIEW

The June 2017 ASAOC states "The Pre-RD Group proposes to conduct a comprehensive 2017/2018 synoptic sampling program of surface sediment, select sediment cores, fish tissue, surface water, background porewater, and bathymetry/fish tracking studies."

Sediment sampling summary:

Two kinds of surface sediment data were collected in the Portland Harbor Superfund Site (i.e., Site)

- Baseline random stratified samples within a grid system (for long-term monitoring) (N=424 samples)
- and discrete targeted samples located in sediment management areas (SMAs) to support further refinement of the SMA footprints (N=231 samples).

Core (subsurface) samples were collected (N=90).

Surface sediment samples were collected from the Downtown Reach (N=29) and the background Upriver Reach (N=30). This area is collectively referred to as the D/U Reach.

To date, EPA has received the surface sediment, subsurface sediment, round 1 sediment trap, round 1 surface water, fish tissue, and background porewater data as well as the fish tracking three-month field summary report. **The surface sediment data from within the Site and D/U Reach are now complete and are presented and analyzed below.**

QUESTION: ARE THERE SIGNIFICANT DIFFERENCES?

Three aspects of this question will be reviewed.

1) Location (Have areas of contamination changed?)

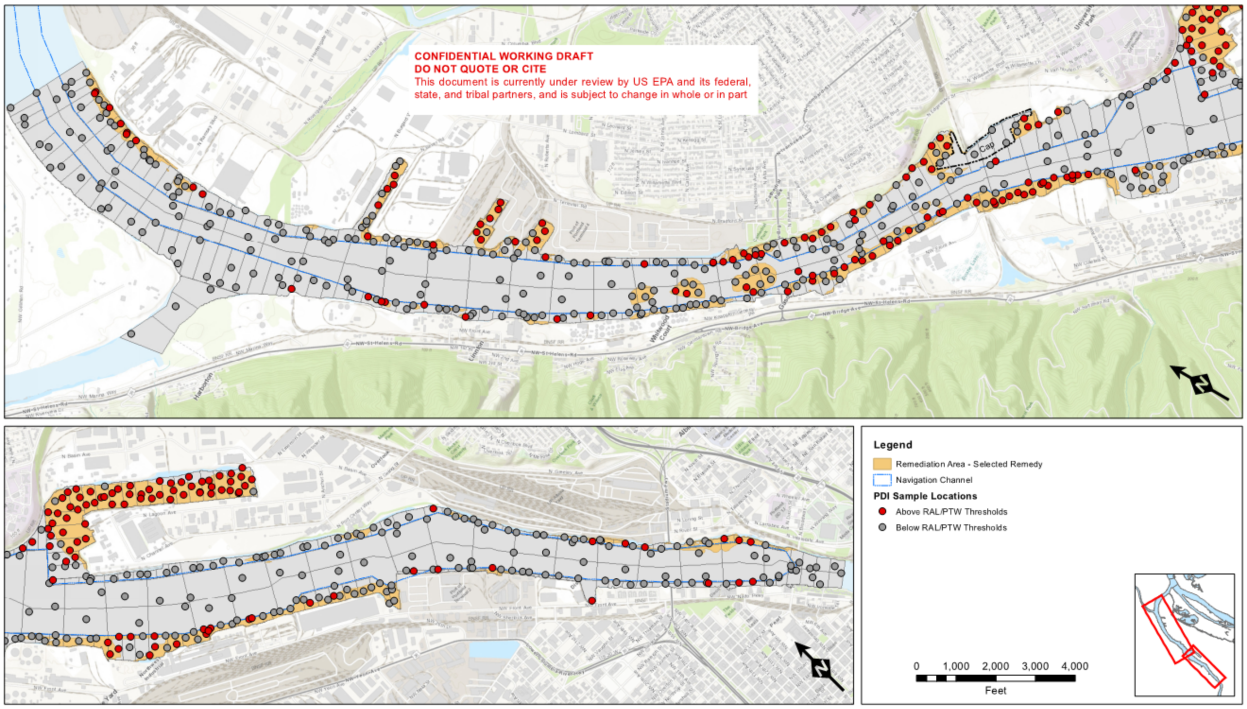
2) Concentrations (Have contamination levels changed?)

3) Equivalence (How do the current Site concentrations compare to the background Upriver Reach?)

1. Location (Have areas of contamination changed?)

a. Results

Table 21 of the Record of Decision (ROD) lists the 11 contaminants of concern that drive the areas of active sediment remediation in the Site. These COCs are broken down into the 6 focused COCs which have remedial action levels (RALs) and the 5 additional contaminants that are considered Principal Threat Waste (PTW) and have threshold concentrations as well. **Figure 1** shows 2018 surface sediment samples that exceed RALs and/or PTW thresholds compared to the ROD's SMA footprint. Results from individual COCs are provided in Supplemental Data Figures. Note: chlorobenzene was not included in the 2018 sampling.



Surface Sediment Sample Locations above RALs (2018)

Figure 1. 2018 Baseline and SMA sample locations compared against the Selected Remedy SMAs.

b. Analysis

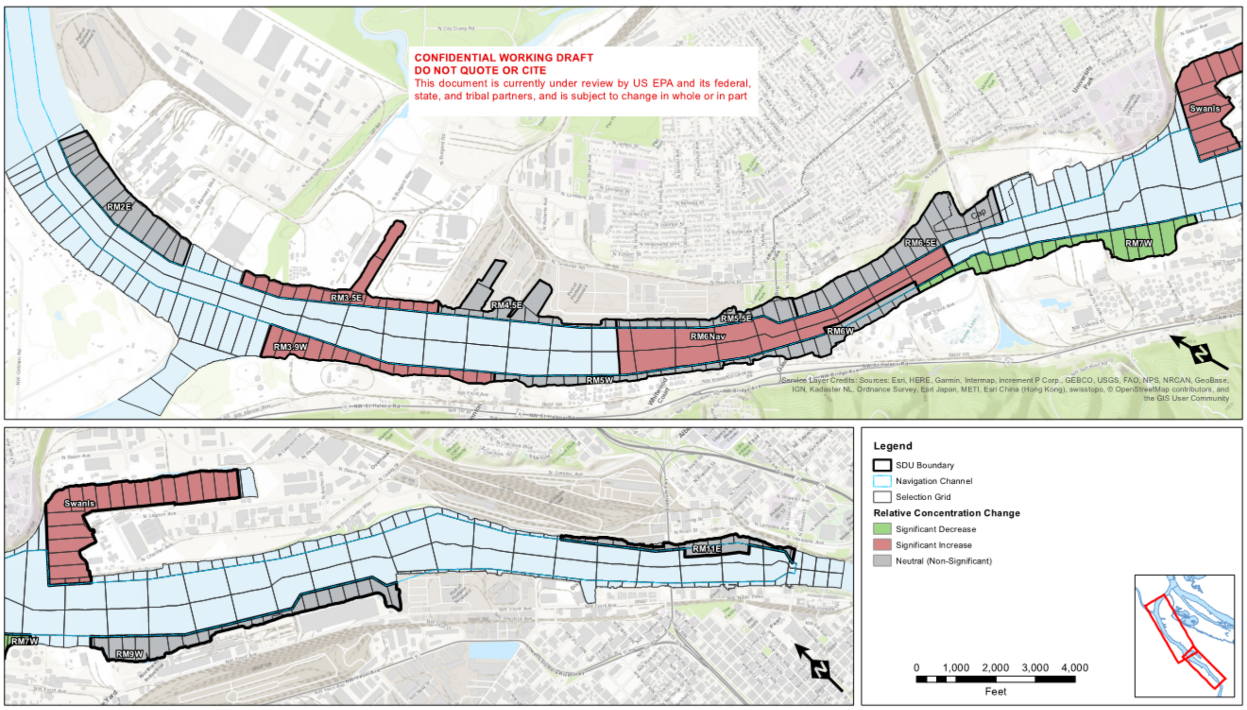
Generally, most of the surface areas with RAL exceedances in the ROD still have RAL exceedances. There have not been major shifts in the sediment "hot-spots" and contaminated areas are generally still contaminated. In some areas, RAL exceedances are no longer present on the surface, while in others, RAL exceedances are present in areas not seen in the ROD. During full remedial design, higher density sampling will be needed to fully and appropriately delineate the SMAs in both the surface and subsurface sediments.

2) Concentrations (Have contamination levels changed?)

a. Results

To address this question, it is necessary to clarify "Over what area and COC?". Portland Harbor is a large site, where contaminated areas are interspersed among broad, relatively clean areas. As a result, Site-wide concentrations can mask localized conditions and site-specific changes. SDUs (sediment decision units) were used in the ROD to depict conditions in the most contaminated areas. The SDUs are approximately 1 mile in river length, centered on the most contaminated areas. The figures below focus on concentration changes of the ROD Table 21 COCs in the SDUs.

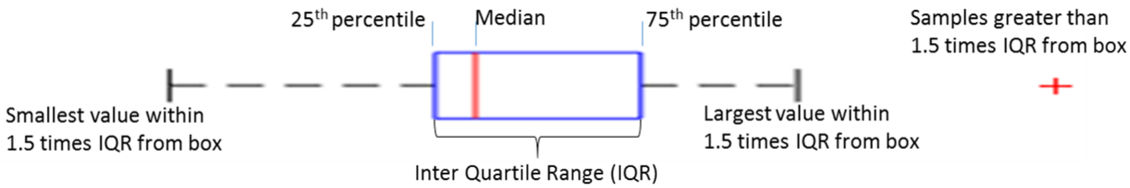
Figure 2 shows the outcomes of statistical tests that evaluated whether the 2018 SDU COC concentrations were significantly different than concentrations from the RI/FS data set. This analysis condenses the range of COCs into a single comparison where gray SDUs have no statistical differences; red SDUs show significant increases, and green SDUs show significant decreases.



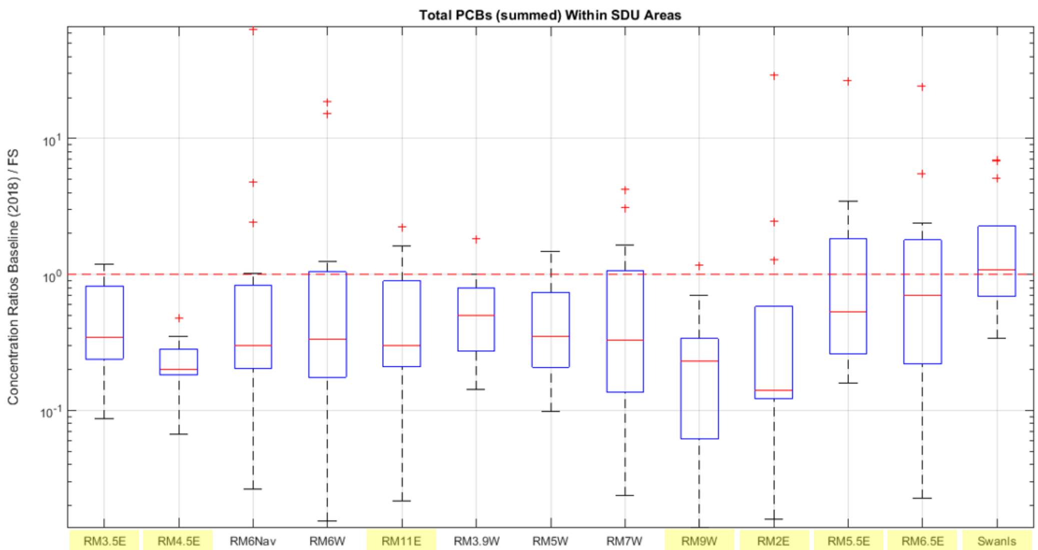
Sediment Decision Unit Focused COCs Relative Concentration Change (2018 Samples)

Figure 2. Relative concentration change between the 2018 (Baseline and SMA) and the RI/FS samples for SDUs.

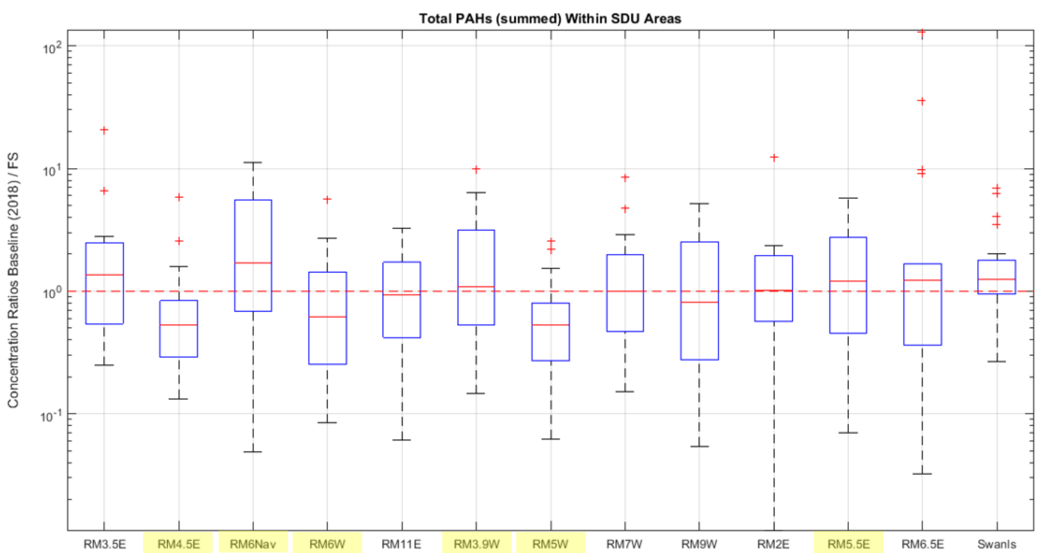
Figures 3a-f present the SDU and focused COC data in greater detail. Here, the 2018 data are compared to the RI/FS data for each SDU (the data distribution includes results from each of the cells in the sampling grid of the SDU). The data are presented as a ratio (new/old) so that the degree of change can be readily discerned. Box and whisker plots for the additional COCs are included in the Supplemental Data Figures.

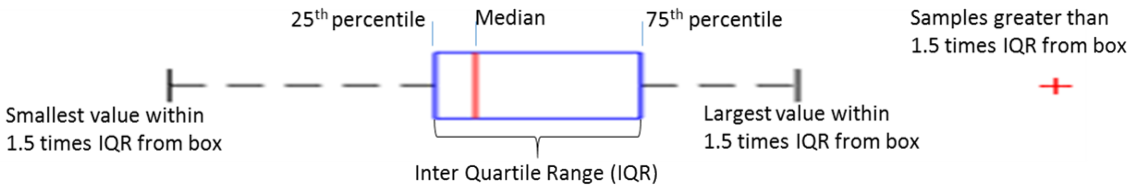

25th percentile
Median
75th percentile
Samples greater than 1.5 times IQR from box
Smallest value within 1.5 times IQR from box
Largest value within 1.5 times IQR from box
Inter Quartile Range (IQR)

a)

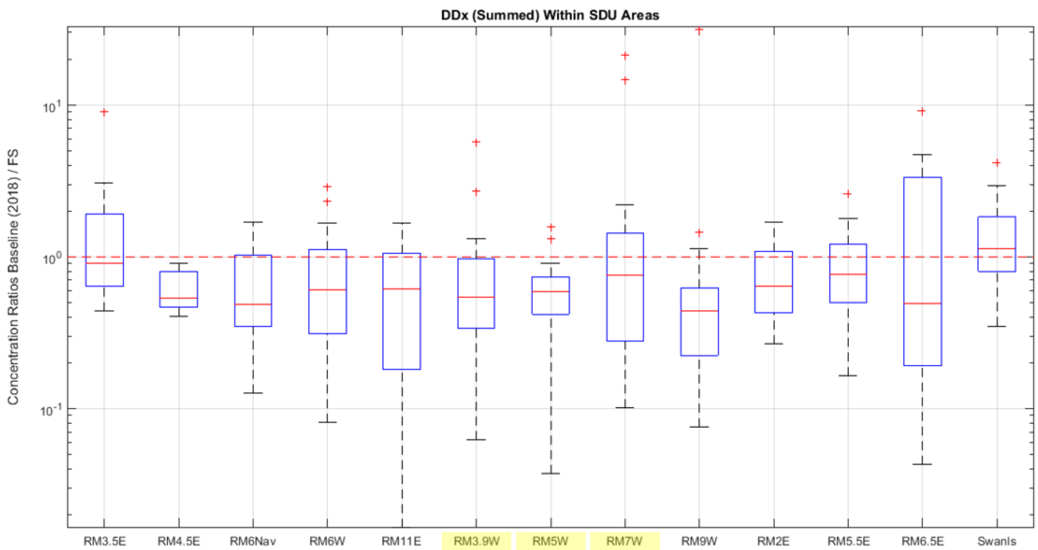

Total PCBs (summed) Within SDU Areas
Concentration Ratios Baseline (2018) / FS
10^1
10^0
10^-1
RM3.5E
RM4.5E
RM6Nav
RM6W
RM11E
RM3.9W
RM5W
RM7W
RM9W
RM2E
RM5.5E
RM6.5E
SwanIs

b)

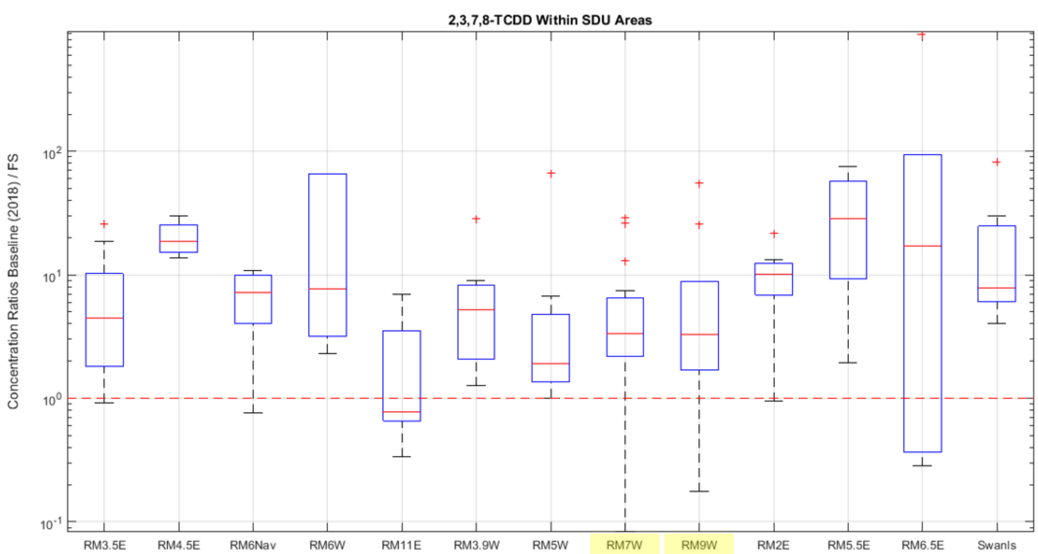

Total PAHs (summed) Within SDU Areas
Concentration Ratios Baseline (2018) / FS
10^2
10^1
10^0
10^-1
RM3.5E
RM4.5E
RM6Nav
RM6W
RM11E
RM3.9W
RM5W
RM7W
RM9W
RM2E
RM5.5E
RM6.5E
SwanIs

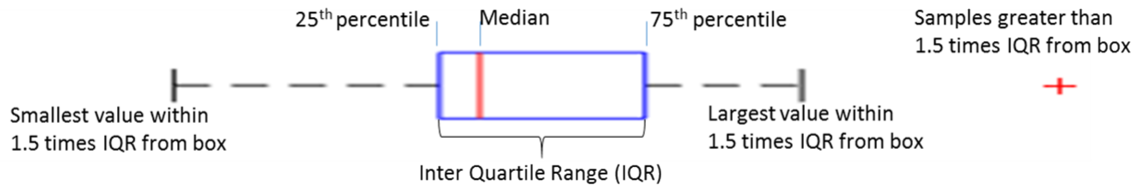

25th percentile
Median
75th percentile
Samples greater than 1.5 times IQR from box
Smallest value within 1.5 times IQR from box
Largest value within 1.5 times IQR from box
Inter Quartile Range (IQR)

c)

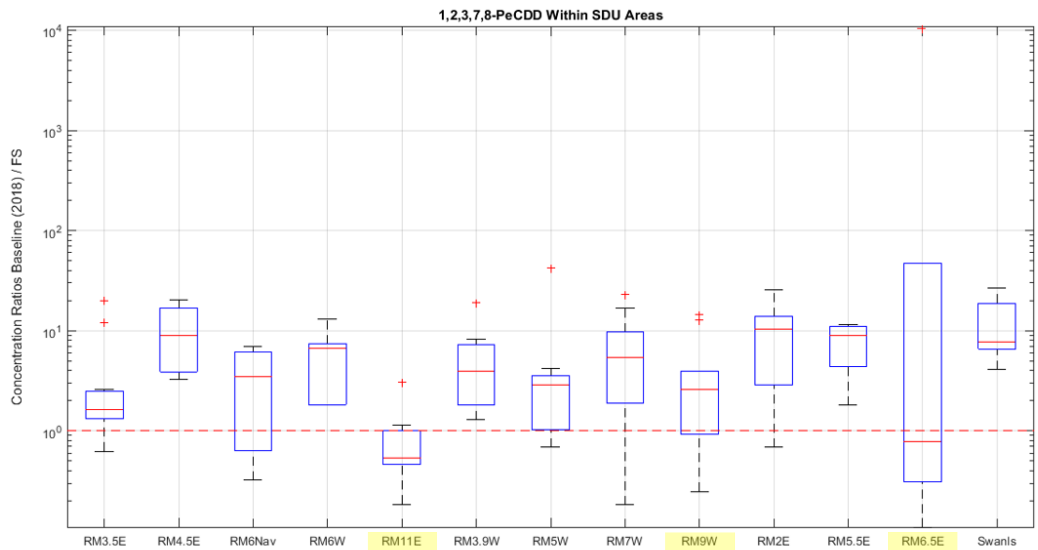

DDx (Summed) Within SDU Areas
Concentration Ratios Baseline (2018) / FS
RM3.5E
RM4.5E
RM6Nav
RM6W
RM11E
RM3.9W
RM5W
RM7W
RM9W
RM2E
RM5.5E
RM6.5E
SwanIs

d)


2,3,7,8-TCDD Within SDU Areas
Concentration Ratios Baseline (2018) / FS
RM3.5E
RM4.5E
RM6Nav
RM6W
RM11E
RM3.9W
RM5W
RM7W
RM9W
RM2E
RM5.5E
RM6.5E
SwanIs



e)



f)

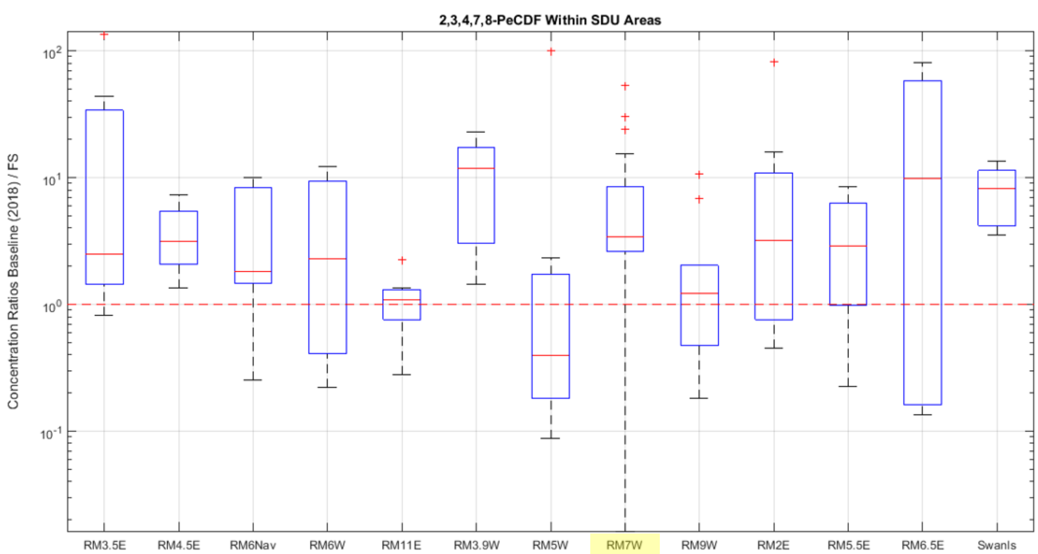
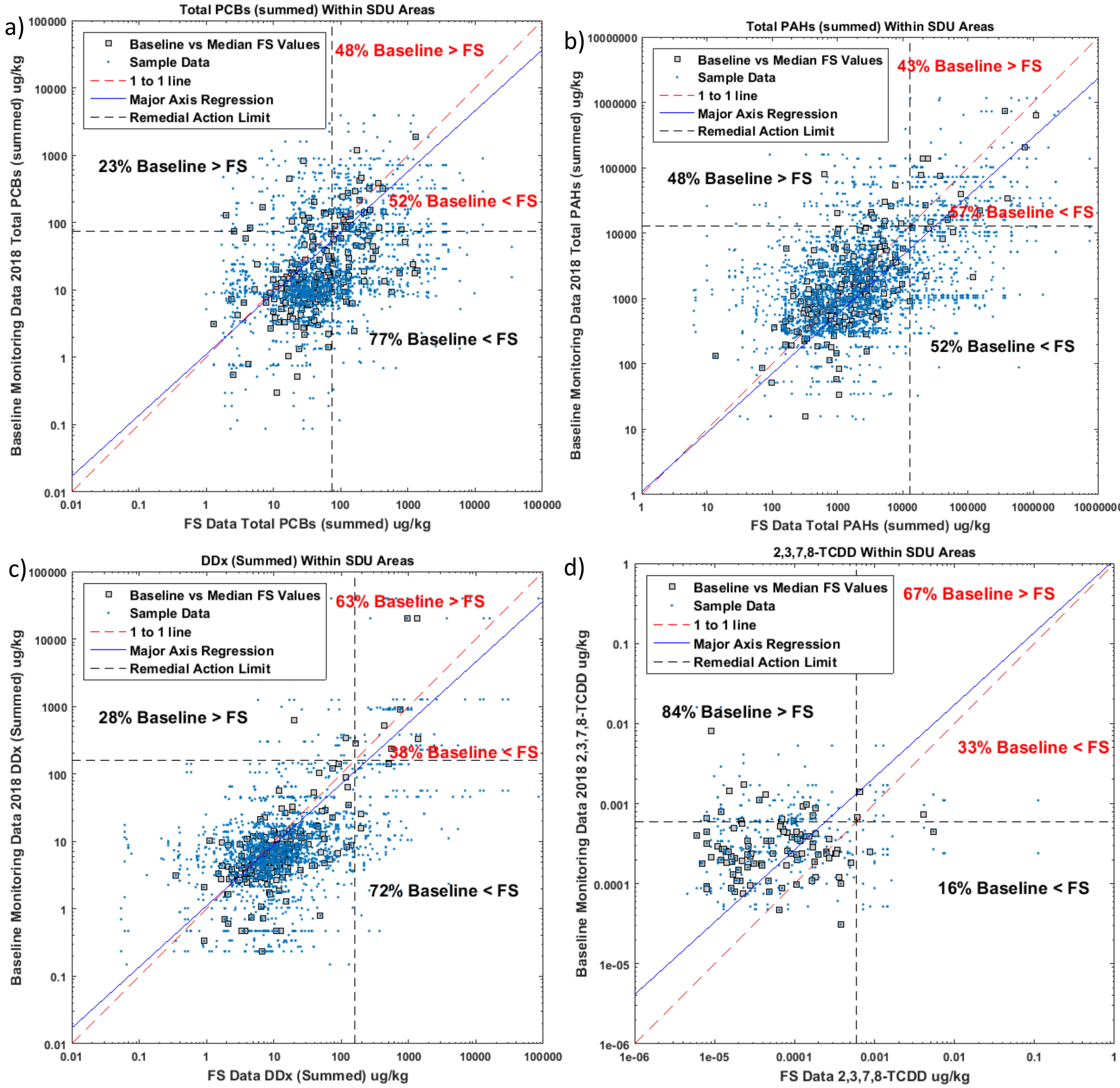
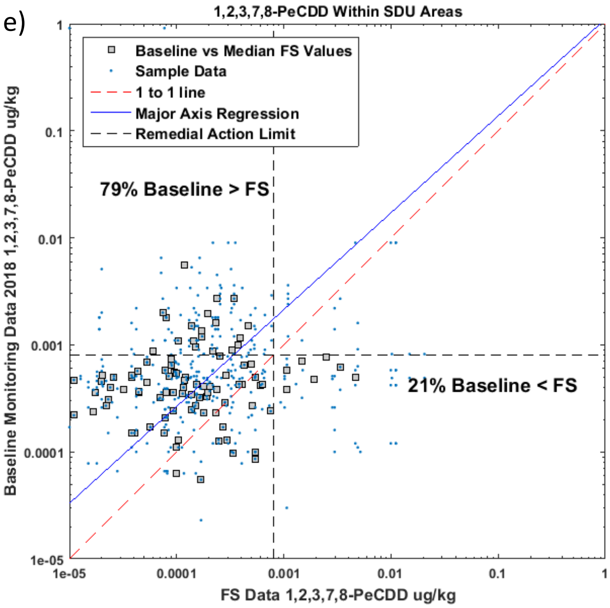


Figure 3. Ratio of 2018 Baseline concentrations to median FS concentrations in corresponding baseline sampling grid cells for a) total PCBs, b) total PAHs, c) DDx, d) 2,3,7,8-TCDD, e) 1,2,3,7,8-PeCDD, and f) 2,3,4,7,8-PeCDF. Ratios less than one indicate declines in concentration and boxes that overlap the red dashed line at 1.0 are indicative of little change. Yellow highlight indicates that a focused COC is a predominant contaminant in that SDU.

Figures 4a-f compare the 2018 data to the RI/FS data for each of the 428 cells in the 2018 sampling grid (note that not all cells had RI/FS data for comparison). Each figure presents a different COC. Data points in the upper right quadrant of each figure are the cells above RALs for both the RI/FS and 2018 data. Points above the 1:1 line are cells where the concentration has increased. Points below the line are cells where the concentration decreased. Percentages of the cells that increased or decreased are presented in the figures (Site-wide is black text; RAL exceedance areas are red text). Regression plots for the additional COCs are included in the Supplemental Data Figures.



e)



f)

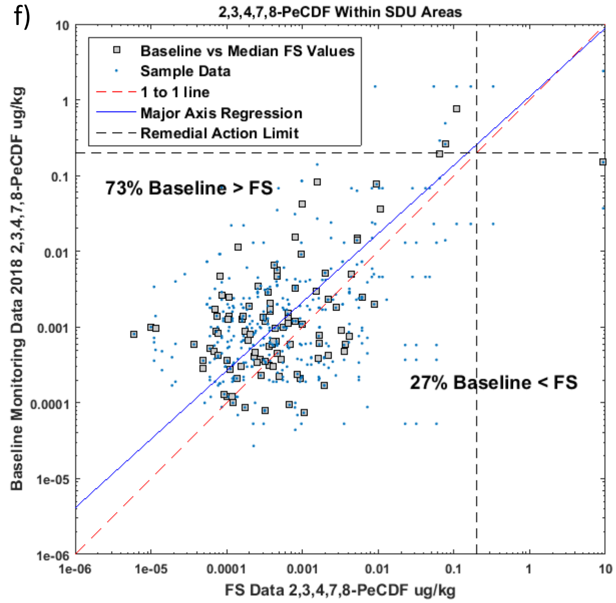


Figure 4. Concentration in 2018 Baseline samples plotted against multiple concentrations in FS samples within the same baseline sampling grid cell for a) total PCBs, b) total PAHs, c) DDx, d) 2,3,7,8-TCDD, e) 1,2,3,7,8-PeCDD, and f) 2,3,4,7,8-PeCDF. Gray squares represent the median (50th percentile) of the FS samples. Black percentages are the percent of cells in the Site that increased or decreased. Red percentages are the percent of the cells with concentrations greater than RALs for both the RI/FS and 2018 data that increased or decreased.

An important caveat is that the analyses above depict evaluations of data from the cells of the 2018 sampling grid (cell boundaries are shown in **Figures 1 and 2**). These grid cell sizes range from 0.3 acres to 25 acres. This comparison is premised on the assumption that both the 2018 and RI/FS samples are appropriate and comparable representations of that cell. That may not always be the case; however, the assumption is necessary if the RI/FS data are to be compared to the 2018 data.

b. Analysis. Compared to the RI/FS data (collected between 1997 and 2008), the COC levels in 2018 have often (but not always) declined, depending on the COC and SDU. **Figure 2** evaluates whether concentrations have changed *significantly* in the SDUs. The analysis shows that 8 out of 13 SDUs had non-significant changes from the RI/FS to the 2018 data. Four areas showed a significant increase while only one showed a significant decrease. **Figures 3a-f** show variation in COC changes between SDUs and COCs, with some decreases and some increases. **Figures 4a-f** contain all the Site data for individual COCs and depicts the percent of the sampling grid cells that increase or decrease. The upper right quadrant focuses on areas of the Site above RALs for both the RI/FS and 2018 data. The analysis shows that in the most heavily contaminated areas (areas greater than RALs), DDx and TCDD concentrations may have increased in more cells than decreased. When the entire river is considered, more cells decreased than increased.

Generally, the results were consistent with the Site's conceptual site model. The ROD envisioned that natural recovery would occur over much of the Site, with decreases in sediment concentrations due to upland source control and sediment deposition. Some area and COC combinations reflect those declines. Other areas that are less prone to natural recovery do not appear to have declined. As a decision framework, the ROD was designed to incorporate new data and accommodate the changes that have taken place over the 10-20 years since the RI/FS data were collected. During the design process, surface and subsurface data from 2018 will be used in conjunction with higher-resolution design samples to refine SMA footprints and determine further actions.

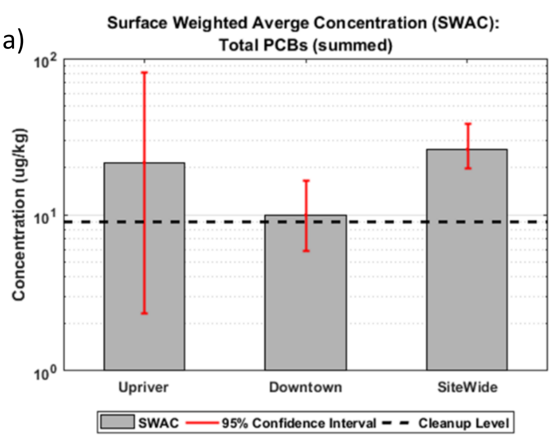
3) Equivalence (How do the current Site concentrations compare to the background Upriver Reach?)

a) Results

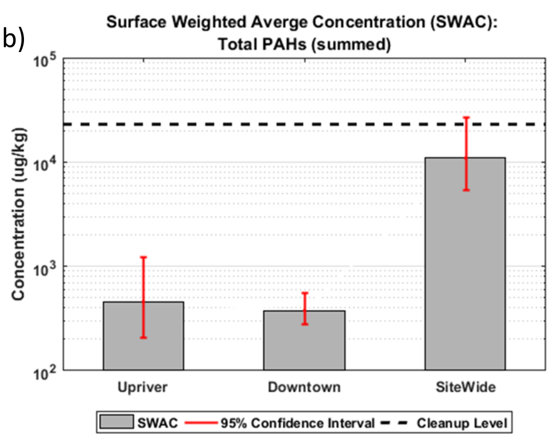
To assess current sediment conditions in a statistically sound way, surface area weighted average concentrations (SWACs) are calculated. By area-weighting and only using the unbiased Baseline samples, an unbiased estimate of the average concentrations can be calculated. These SWACs can be compared against the cleanup levels to determine how close or far average concentrations are from achieving the remedy goals. An added benefit to only using the unbiased Baseline samples in the SWAC calculations is the ability to assess the uncertainty in these SWAC estimates. Uncertainty is represented by 95% confidence intervals around the SWAC.

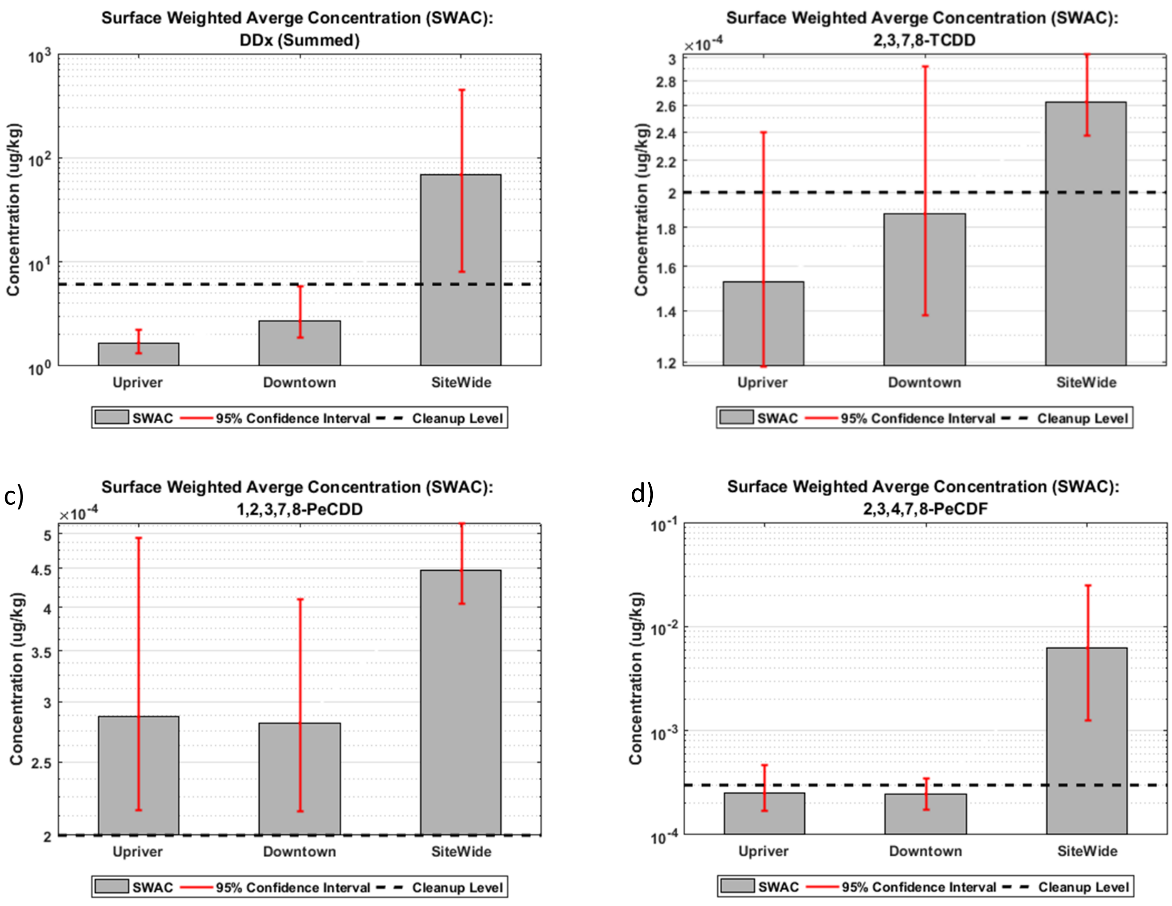
Figures 5a-f show the SWACs and their error bars for the focused sediment COCs. Each figure presents a different COC and shows the sediment cleanup level for that respective COC. Note that for total PAHs the cleanup level is higher than the SWAC; this cleanup level is based on ecological risk to the organisms living in the surface sediment. However, the SWAC for carcinogenic PAHs, a subset of total PAHs, has a much lower cleanup level due to their cancer risk in humans. SWAC figures for the additional COCs are provided in the Supplemental Data Figures.

a)



b)





e)
f)

Figure 5. Surface sediment SWACs for a) total PCBs, b) total PAHs, c) DDx, d) 2,3,7,8-TCDD, e) 1,2,3,7,8-PeCDD, and f) 2,3,4,7,8-PeCDF. The 95% confidence intervals are denoted by the red bars and the cleanup level is the black dashed line.

Additionally, to evaluate remedial effectiveness before, during, and after the cleanup, sediment concentrations within the Site are compared to those in the background Upriver Reach. This comparison is called equivalence and is based on the ratio of the Site and Upriver Reach geometric means. When the 95% upper confidence limit (UCL) for the ratio is less than 1.5, then the Site and background area are deemed to be statistically equivalent and the remedy is working as planned.

Figure 6 shows the ratios of geometric means for the Table 21 COCs between the Site and the background Upriver Reach. The red dashed line is positioned at 1.5 and represents the limit that the 95% UCL must be below to declare equivalence. Equivalence figures for the Site and the Downtown Reach as well as the Downtown and the Upriver Reaches are provided in the Supplemental Data Figures.

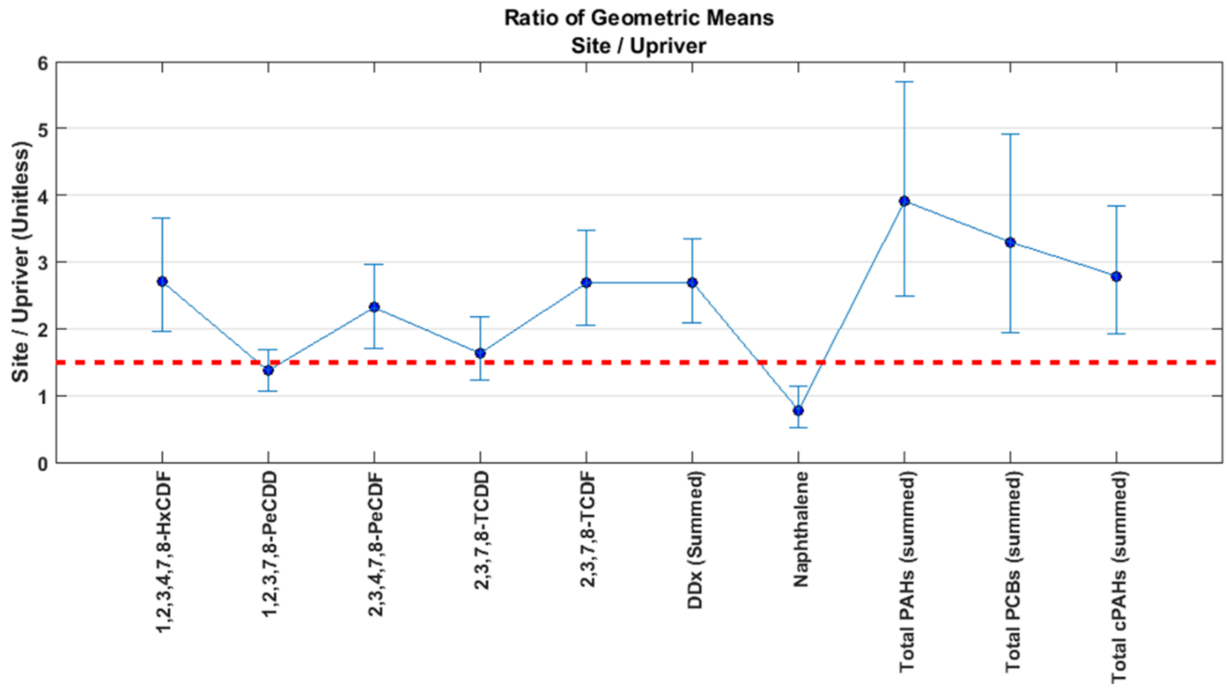


Figure 6. Ratio of Site and Upriver Reach (background) geometric means for the Table 21 COCs. The red dashed line denotes the equivalence threshold of 1.5.

b) Analysis

For all 6 of the focused COCs, the surface sediment SWACs are higher in the Site than in the background Upriver Reach. **Figures 5a, d, and e** show wide 95% confidence intervals in the Upriver Reach that overlap the confidence intervals of the Site for PCBs, TCDD, and PeCDD. These are due to a limited number of samples collected in 2018 in the Upriver Reach (N=30) and a wide range of concentrations observed. Additionally, the overlap of the 95% confidence intervals between the Site and the Upriver Reach indicate that there are not enough Upriver Reach samples to accurately determine equivalence. Further sampling of the Site and Upriver Reach will be required in tandem with the cleanup to ensure that equivalence is being met. As additional sampling is performed, the wide confidence intervals will get smaller and allow for conclusive determinations of equivalence.

As shown on **Figure 6**, the 95% UCLs for the ratio of the geometric means are all greater than 1.5 for all of the Table 21 COCs except for naphthalene. Surface sediment concentrations in the Site are not close to achieving equivalence with the background Upriver Reach and there is an immediate need to move forward with Remedial Design and Remedial Action.

Abbreviations and definitions.

COC: Contaminant of Concern. Portland Harbor uses PCBs, PAHs, DDT, and Dioxin/Furans as focused COCs.

D/U Reach. Downtown and Upriver Reach. The Downtown Reach is immediately upstream of the Superfund Site and the Upriver Reach is the background reference area further upstream.

PTW: Principal Threat Waste. Source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment.

RAL: Remedial Action Level. The sediment COC concentration that is used to delineate SMAs and is the threshold for active remediation.

ROD: Portland Harbor Superfund Site Record of Decision.

SMA: Sediment Management Area. Areas where RALs are exceeded. The ROD states that active remediation will occur in areas with RAL exceedances.

SDU: Sediment Decision Unit. The most contaminated areas of the river. SDU boundaries are approximately 1-mile reaches centered on the most heavily contaminated areas.

Site: Portland Harbor Superfund Site

SWAC: Surface Area Weighted Average Concentration. The most statistically correct way to determine average concentrations for a given area. SWACs are compared against the cleanup levels to assess how effective the remedy is.

UCL: Upper Confidence Limit. Refers to the 95% upper confidence limit and indicates that we have 95% confidence that the true geometric mean will be less than this value.

DELIBERATIVE-DRAFT Memorandum

To: *Sean Sheldrake, United States Environmental Protection Agency Region 10*

From: *CDM Smith*

Date: *March 21, 2019*

Subject: *Subsurface Sediment RAL Exceedances in Areas of Dioxin/Furan Surface Contamination*

Introduction

Polychlorinated dibenzo-p-dioxin/furan (dioxin/furan) congeners are five of the eleven contaminants of concern (COCs) that drive the areas of active sediment remediation in the Portland Harbor Superfund Site (Site). These COCs are listed on Table 21 of the Record of Decision (ROD) and are:

- 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)
- 2,3,7,8-tetrachlorodibenzofuran (TCDF)
- 1,2,3,7,8-pentachlorodibenzo-p-dioxin (PeCDD)
- 2,3,4,7,8-pentachlorodibenzofuran (PeCDF)
- 1,2,3,4,7,8-hexachlorodibenzofuran (HxCDF)

TCDD, PeCDD, and PeCDF are sediment focused COCs and TCDF and HxCDF have Principal Threat Waste (PTW) concentration thresholds due to their widespread distribution and toxicity. Dioxins/furans are carcinogenic, bioaccumulative, and pose significant human health and ecological risks at very low concentrations (EPA 2016a). Additionally, concentrations in sediment and biota are generally low and stretch the limits of the best available laboratory methods leading to difficulties in measurement and interpretation of results.

Development of Site Dioxin/Furan Cleanup Levels and Remedial Action Levels

The Remedial Investigation/Feasibility Study (RI/FS) surface sediment samples analyzed for dioxins/furans are in targeted areas of the Site and have less spatial coverage than the other COCs. However, additional samples were collected in the Upriver Reach to define background concentrations. To adequately address dioxin/furan contamination at the Site, the ROD established individual sediment and fish tissue cleanup levels (CULs) for TCDD, TCDF, PeCDD, PeCDF, and HxCDF. These five dioxin/furan congeners contribute greater than 85 percent (%) of the estimated cancer risk and non-cancer hazard associated with fish consumption (EPA 2017, 2016b). The CULs for fish tissue are risk-based while the sediment CULs are based on concentrations in the background reference area (i.e., Upriver Reach). The use of background concentrations for CULs is described in Section 9.1.4 of the ROD as follows: “If background concentrations are higher than the cleanup level, EPA defaults to the background concentration as a matter of policy” (EPA 2017).

The background concentrations for dioxins/furans were developed using the RI/FS sediment data collected in the Upriver Reach. These background RI/FS dioxin/furan data have frequencies of detection much less than 50% for TCDD, TCDF, PeCDD, and PeCDF making it inappropriate to calculate upper confidence limits (UCLs) using only the detected results. Instead, the background concentrations, and hence the ROD Table 17 CULs, were established as the 95% UCL of the method detection limits (corrected upwards for the organic carbon content).

The remedial action levels (RALs) for the focused COCs and PTW thresholds selected in the ROD are concentrations above which dredging and/or capping needs to occur to effectively reduce risks in a reasonable timeframe. The PTW thresholds for dioxins/furans are risk-based concentrations (1 in 1,000 cancer risk) while the RALs are based on the relationship between achieving CULs, surface-area weighted average concentrations, and the number of acres remediated. Since the dioxin/furan CULs are based on background concentrations, the RALs for TCDD, PeCDD, and PeCDF are also tied to background.

Subsurface Sediment RAL Exceedances in Areas of Dioxin/Furan Surface Contamination

The 2018 Pre-Design Investigation (PDI) sampling provided the first Site-wide spatial coverage of dioxins/furans in the surface sediment. These new data, in combination with the RI/FS data, have allowed for better delineation of sediment management areas (SMAs) using the ROD interpolation method. These interpolated SMAs in the ROD, while appropriate for +50/-30 decision making, only use the surface sediment and are insufficient for remedial design. However, this method can be used to approximate the contribution of dioxins/furans to the lateral extent of the surface sediment SMA. **Figure 1** shows that the interpolated SMA containing both the RI/FS and PDI data is approximately 375 acres with 71 acres being due to dioxins/furans alone (orange hashed areas).

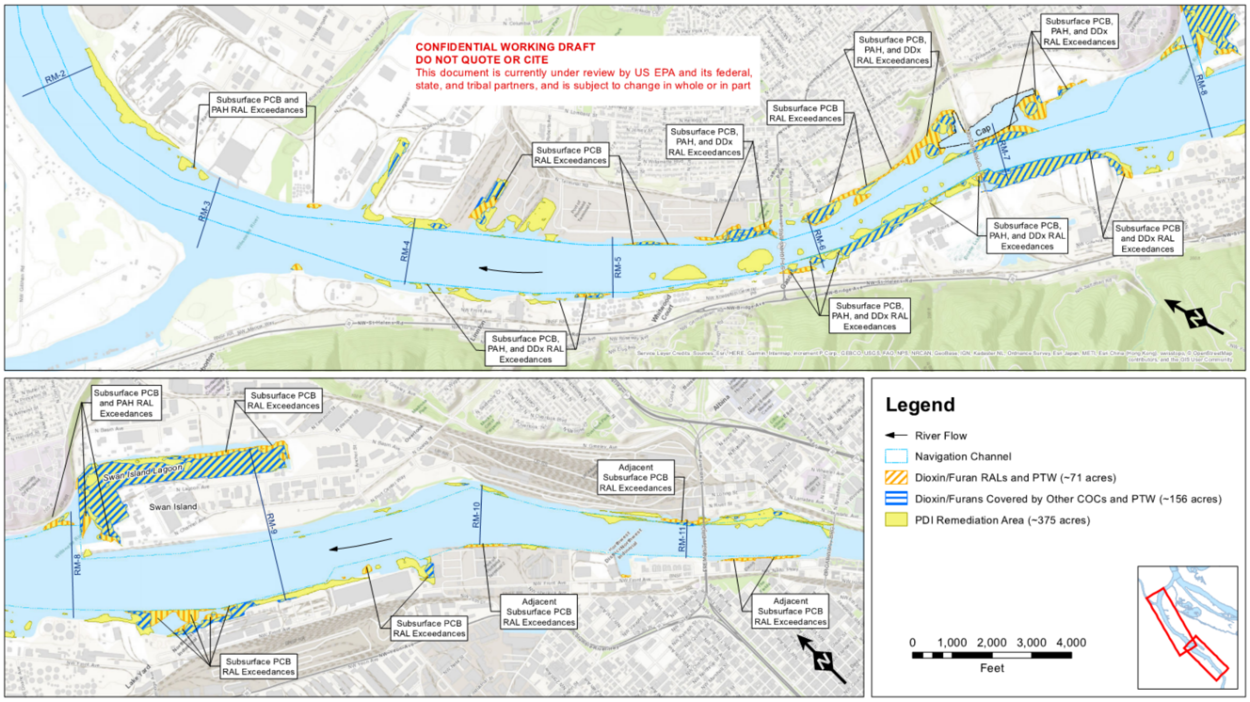


Figure 1. Surface-only SMA footprint map with the RI/FS and PDI data using the ROD interpolation method. Yellow is the overall remediation area while the orange hash shows areas of RAL or PTW exceedances for dioxins/furans alone. The blue hash areas show where other COCs are comingled with dioxins/furans at the surface.

However, nearly all the areas of dioxin/furan surface contamination are comingled with or adjacent to subsurface RAL exceedances for polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and/or DDx (dichlorodiphenyldichloroethane [DDD] + dichlorodiphenyldichloroethene [DDE] + dichlorodiphenyltrichloroethane [DDT]). These subsurface RAL exceedances for PCBs, PAHs, and DDx indicate that despite the presence of only dioxin/furan contamination at the surface, contamination from the other focused COCs remain at depth that need to be further investigated during remedial design.

Equivalence between Site and Upriver Reach

To evaluate remedial effectiveness before, during, and after the cleanup, surface sediment concentrations within the Site are compared to those in the Upriver Reach where background concentrations are defined. This comparison is called equivalence and is based on the ratio of the Site and Upriver Reach geometric means. When the 95% UCL for the ratio is less than 1.5, then the

Site and background area are deemed to be statistically equivalent and the remedy is working as planned.[1]

Despite the current limited temporal dataset, an equivalence evaluation was performed using only the unbiased samples from the 2018 PDI surface sediment dataset allowing for an unbiased estimate of equivalence. This was done to evaluate if the new PDI data are showing concentrations within the Site that are coming into equilibrium with background as a result of sediment deposition since the RI/FS data were collected. Additionally, as the PDI data have higher frequencies of detection for the Upriver Reach dioxins/furans (40-87%) compared to the RI/FS data (2-49%), the equivalence analysis with the PDI data is less sensitive to non-detect samples. **Figure 2** shows the ratios of geometric means for the Table 21 COCs between the Site and the background Upriver Reach in surface sediment. The red dashed line is positioned at 1.5 and represents the limit that the 95% UCL of the ratio of the Site and Upriver Reach geometric means must be below to declare equivalence.

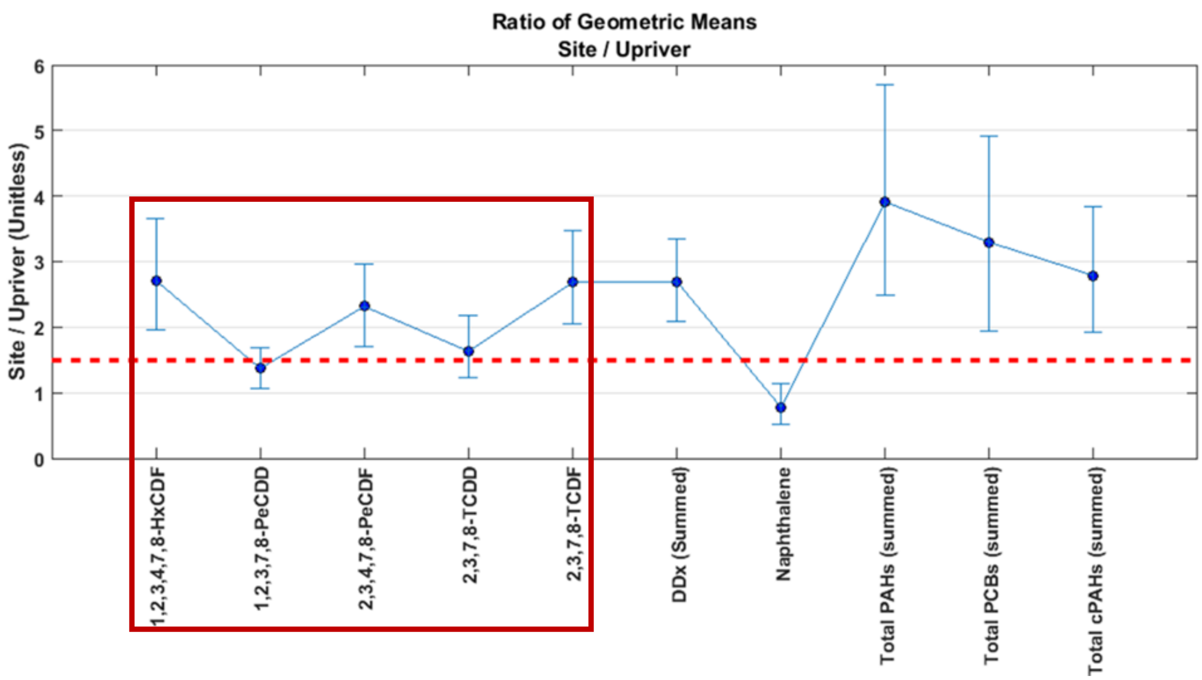


Figure 2. Ratio of Site and Upriver Reach (background) geometric means for the Table 21 COCs. The red dashed line denotes the equivalence threshold of 1.5. Dioxins/furans have been emphasized for illustrative purposes.

According to the equivalence results shown on **Figure 2**, none of the Table 21 COCs have achieved equivalence between the Site and the Upriver Reach except for naphthalene (which is not a

[1] The ratio of 1.5 for determining equivalence allows for uncertainty in the data and may be adjusted based on future statistical evaluations. Determination of whether the Site has reached equivalence with the Upriver Reach requires a series of repeated sampling events conducted as part of the long-term monitoring program.

significant driver of the cleanup). However, TCDD and PeCDD appear to be approaching equivalence; while the ratio of the geometric means for PeCDD is below 1.5, the 95% UCL is above and therefore within the margin of error. Additionally, these two COCs have the lowest RALs/PTW thresholds for the five dioxins/furans due to their high toxicity.

While the frequencies of detection for the PDI samples are higher than the RI/FS, there are more rigorous data handling and analysis procedures for the non-detects that may need to be explored. However, since the ratios are at or above the 1.5 equivalence level, additional analysis may marginally increase the ratio and therefore would not change the conclusion that dioxin/furan concentrations in the Site are not equivalent to the Upriver Reach.

Summary and Conclusions

While the background-derived CULs and RALs represent very low concentrations, estimated dioxin/furan surface SMAs in the Site are comingled with or adjacent to subsurface RAL exceedances for PCBs, PAHs, and DDx. These areas need to be delineated with surface and subsurface sediment samples during remedial design. Additionally, dioxin/furan concentrations in the Site are higher than concentrations in the Upriver Reach based on an equivalence evaluation and the conclusions from this evaluation indicate that remedial action is still necessary to achieve the remedial action objectives laid out in the ROD.

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———. 2016b. Portland Harbor RI/FS, Feasibility Study. Prepared by U.S. Environmental Protection Agency and CDM Smith. June.

cc: Davis Zhen
Hunter Young
Eva DeMaria
Josie Clark
Cami Grandinetti

DELIBERATIVE-DRAFT Memorandum

To: *Sean Sheldrake, US Environmental Protection Agency Region 10*

From: *CDM Smith*

Date: *April 15, 2019*

Subject: *Deposition in Sediment Management Areas and Updated Remedial Action Level Curves*

Introduction

The lower Willamette River, which encompasses the Portland Harbor Superfund Site (Site), is a dynamic river system that experiences episodic deposition and erosion over a range of spatial and temporal scales. Although the Site is net depositional, sediment is not deposited uniformly and some areas are net erosional or in "dynamic equilibrium" and subject to periods of oscillating deposition and erosion. It is therefore important to consider the patterns of deposition and erosion over long time-scales. The sediment management areas (SMAs) identified in the Record of Decision (ROD) receive less sediment deposition than the Site and are more erosional or dynamic. Combined with the high concentrations of the focused contaminants of concern (COCs), the ROD SMAs are resistant to natural recovery and require active remediation. Results from the 2018 bathymetry survey and surface sediment sampling are evaluated for their impact on the SMAs and remedial action levels (RALs) defined in the ROD.

Deposition in Sediment Management Areas

Bathymetry surveys during the Remedial Investigation (RI) were completed in 2002, 2003, 2004, and 2009 with the most recent survey completed in 2018 as part of the Pre-Design Investigation (PDI). These surveys are conducted to measure the sediment bed elevations. By comparing the various surveys over time, a picture of long-term river dynamics can be developed that shows whether an area is consistently depositional, consistently erosional, consistently neutral, or in dynamic equilibrium. **Figures 1a** and **1b** show the distribution of these areas in the ROD SMA footprints and the remainder of the Site area (i.e., outside of the active remediation area).

a)

b)

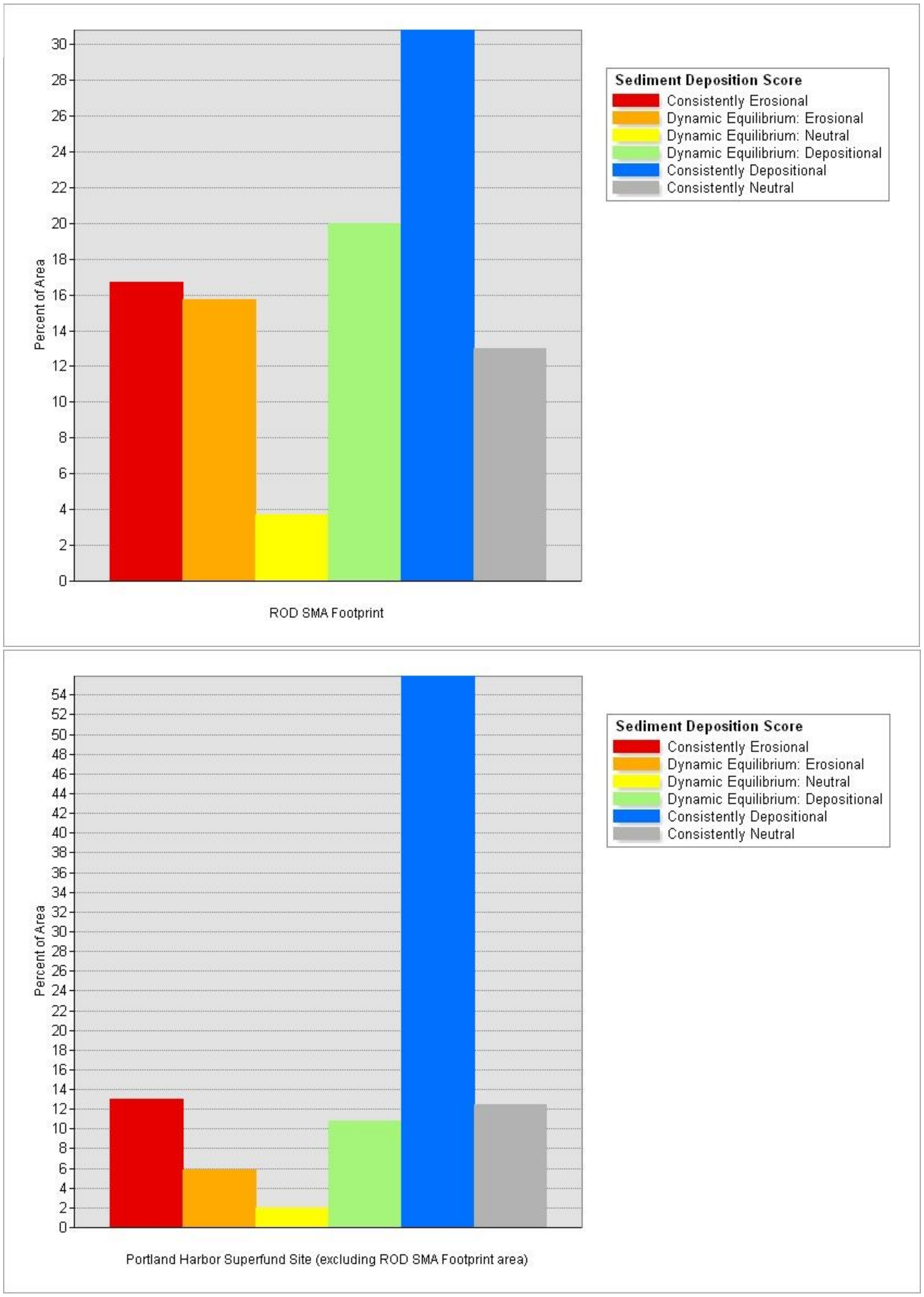


Figure 1. Sediment deposition histograms for a) the ROD SMA footprints and b) the remainder of the Site area.

The bathymetric change analysis suggests that the ROD SMA areas are 30 percent (%) consistently depositional with 70% that are erosional, neutral, or in dynamic equilibrium. Coupled with the high concentrations of focused COCs in these areas, monitored natural recovery (MNR) will not be successful. The results with these new data agree with the evaluations performed during the Feasibility Study (FS) and ROD (EPA 2016, 2017). The areas outside of the ROD SMAs (i.e., remaining Site area) where MNR is the selected technology are 56% consistently depositional with 44% that are erosional, neutral, or in dynamic equilibrium. Additionally, these areas do not have focused COC concentrations greater than RALs and therefore MNR should be successful. **Supplemental Figure S1** shows the spatial distribution of depositional and erosional areas.

The 2004 and 2018 bathymetric surveys were also directly compared to understand the absolute change in sediment bed elevation during this time. The 2004 and 2018 surveys occurred just before comprehensive surface sediment sampling events during the RI and PDI, respectively. Therefore, these two surveys represent the most appropriate points for direct comparison. The results suggest that sediment deposition is not evenly distributed throughout the ROD SMAs. **Figure 2** shows the amount of net deposition in cubic yards that the SMAs (broken up by EPA Proposed Remedial Design Areas) received as well as the average thickness of this deposited sediment. **Supplemental Figure S2** shows the spatial distribution of deposition and erosion from 2004 to 2018.

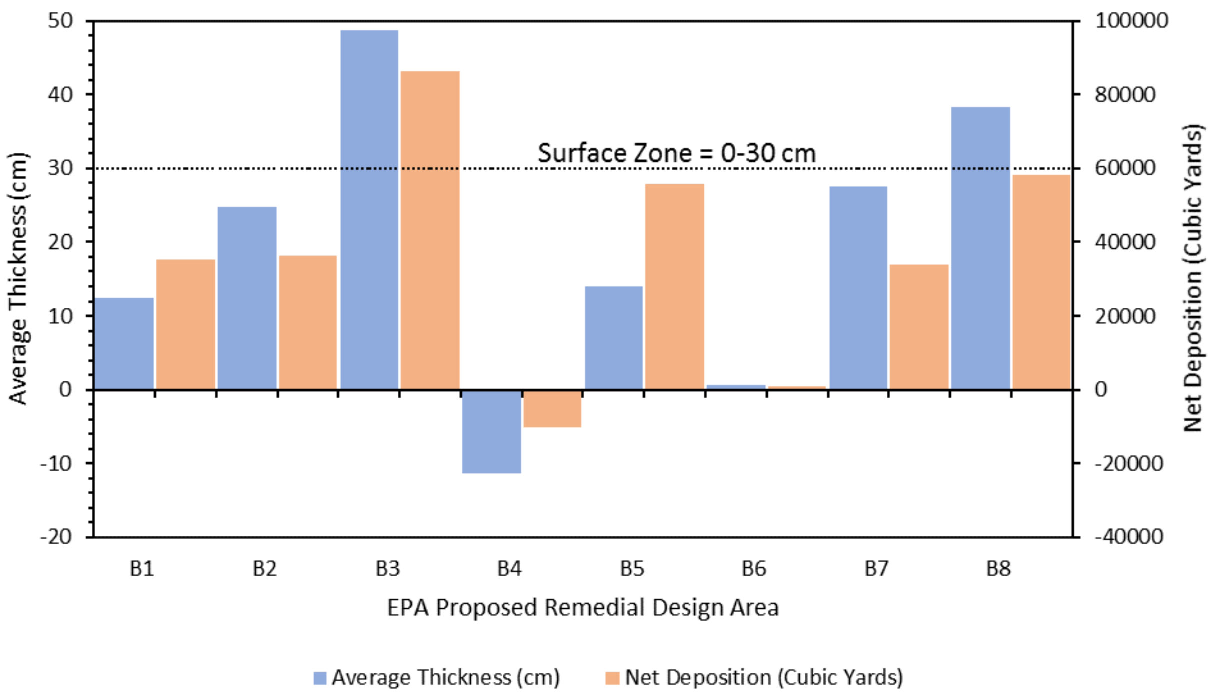


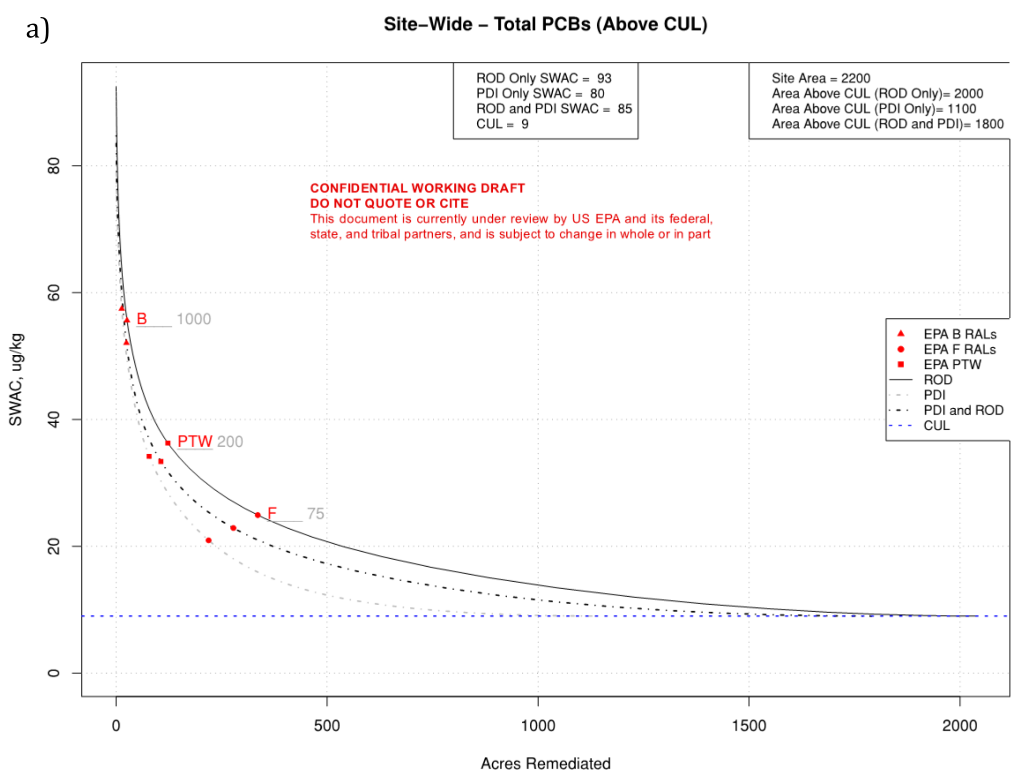
Figure 2. Average new sediment thickness and net sediment deposition in the ROD SMA footprints broken down by EPA Proposed Remedial Design Area.

Sediment deposition varies between areas in the ROD SMAs and ranges from -10,000 cubic yards (i.e., erosion) in the B4 area (RM 11E) to 87,000 cubic yards in the B3 area (RM 9W). This results in average sediment thicknesses of the deposited sediment that range from -12 centimeters (cm) to 49 cm (about 1.5 feet). The zone of surface sediment is defined as the top 30 cm of the sediment bed and only two proposed design areas (B3 and B8) received sediment deposition greater than surface depth thresholds over a 14-year period from 2004 to 2018.

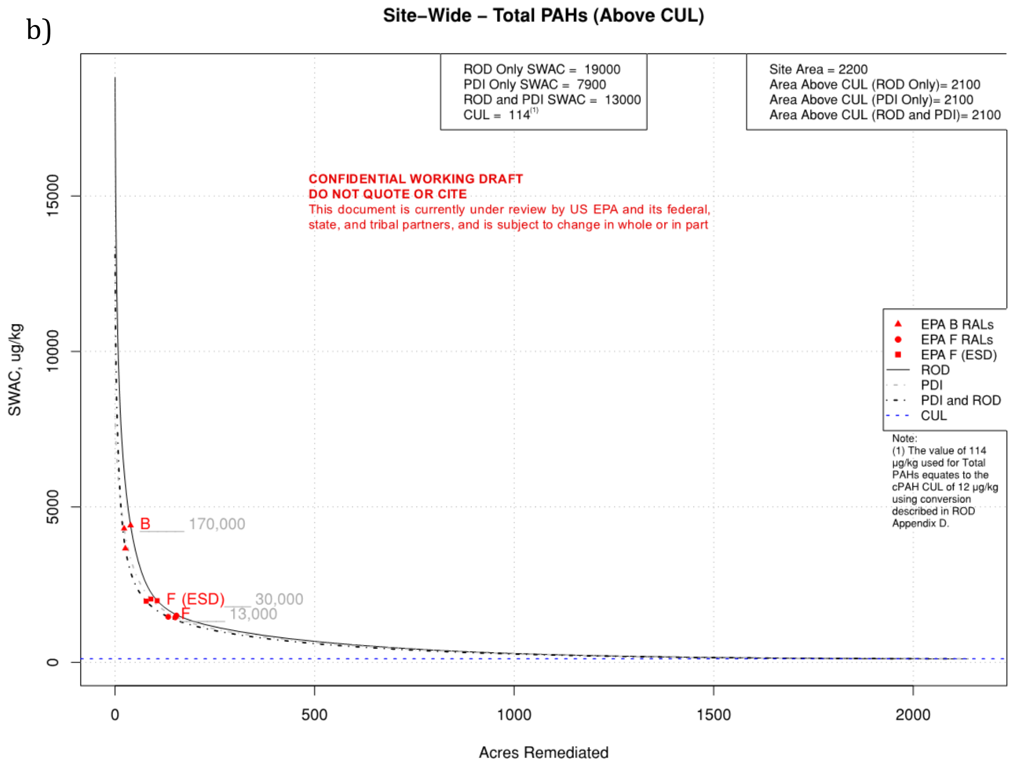
Updated Remedial Action Level Curves

In the ROD, the surface sediment data from the RI/FS were used to develop RAL concentrations for the six focused COCs. The RAL concentrations consider the amount of material that would be addressed to achieve contaminant and risk reductions throughout the Site. This is done with "RAL curve" plots which compare the number of acres remediated against the post-remediation surface area weighted average concentrations (SWACs). The ROD selected higher RALs for the navigation channel ("B" RALs) compared to the remaining Site area ("F" RALs) due to the disconnected exposure pathways in the deeper navigation channel (EPA 2017). Updated RAL curves for the focused COCs were developed with the 2018 PDI surface sediment data to determine whether the relationship between concentration and area remediated have substantially changed since the RI/FS data were collected. **Figures 3a** through **3f** show the RAL curves with data from the ROD only (solid line), PDI only (light dash line), and ROD/PDI combined datasets (dark dash line).

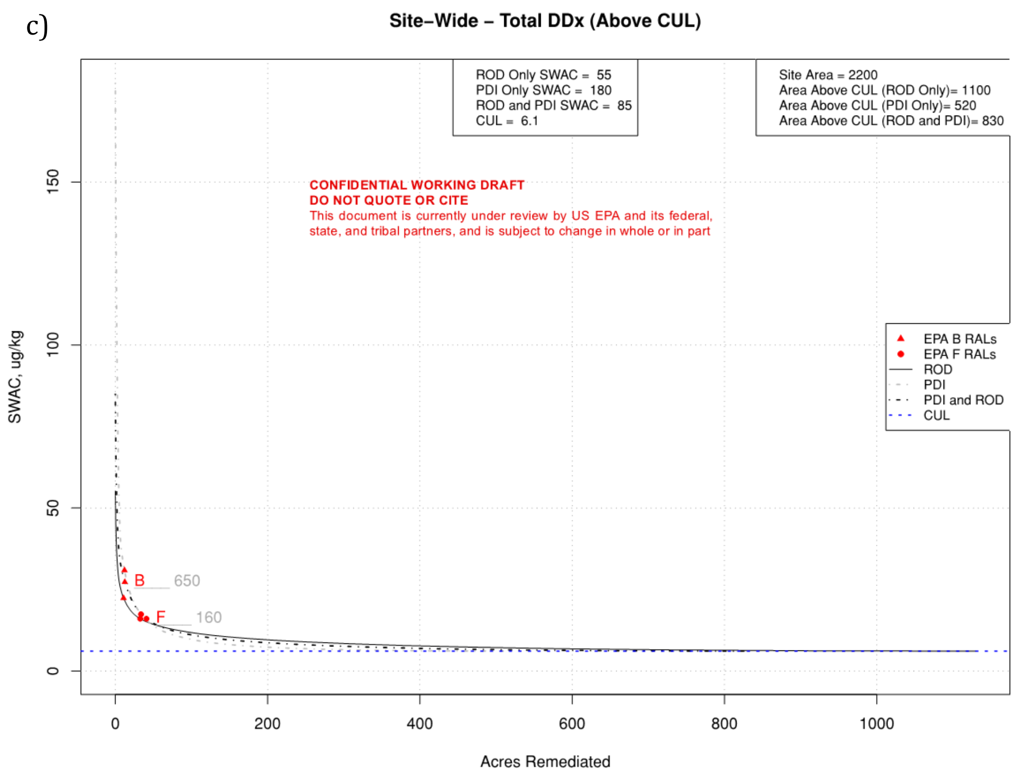
a)



b)


Site–Wide – Total PAHs (Above CUL)
ROD Only SWAC = 19000
PDI Only SWAC = 7900
ROD and PDI SWAC = 13000
CUL = 114(1)
Site Area = 2200
Area Above CUL (ROD Only)= 2100
Area Above CUL (PDI Only)= 2100
Area Above CUL (ROD and PDI)= 2100
CONFIDENTIAL WORKING DRAFT
DO NOT QUOTE OR CITE
This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part
EPA B RALs
EPA F RALs
EPA F (ESD)
ROD
PDI
PDI and ROD
CUL
Note:
(1) The value of 114 µg/kg used for Total PAHs equates to the cPAH CUL of 12 µg/kg using conversion described in ROD Appendix D.
B 170,000
F (ESD) 30,000
F 13,000
SWAC, ug/kg
0
5000
10000
15000
0
500
1000
1500
2000
Acres Remediated

c)


Site–Wide – Total DDx (Above CUL)
ROD Only SWAC = 55
PDI Only SWAC = 180
ROD and PDI SWAC = 85
CUL = 6.1
Site Area = 2200
Area Above CUL (ROD Only)= 1100
Area Above CUL (PDI Only)= 520
Area Above CUL (ROD and PDI)= 830
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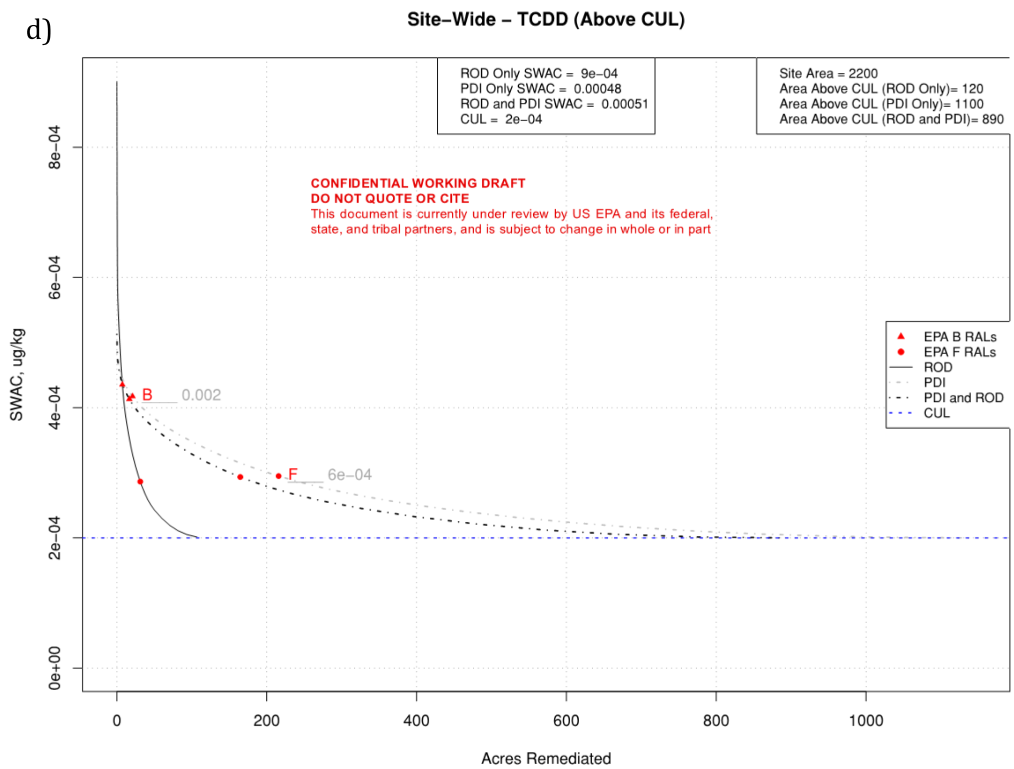
EPA B RALs
EPA F RALs
ROD
PDI
PDI and ROD
CUL
B 650
F 160
SWAC, ug/kg
0
50
100
150
0
200
400
600
800
1000
Acres Remediated

d)


Site–Wide – TCDD (Above CUL)
ROD Only SWAC = 9e–04
PDI Only SWAC = 0.00048
ROD and PDI SWAC = 0.00051
CUL = 2e–04
Site Area = 2200
Area Above CUL (ROD Only)= 120
Area Above CUL (PDI Only)= 1100
Area Above CUL (ROD and PDI)= 890
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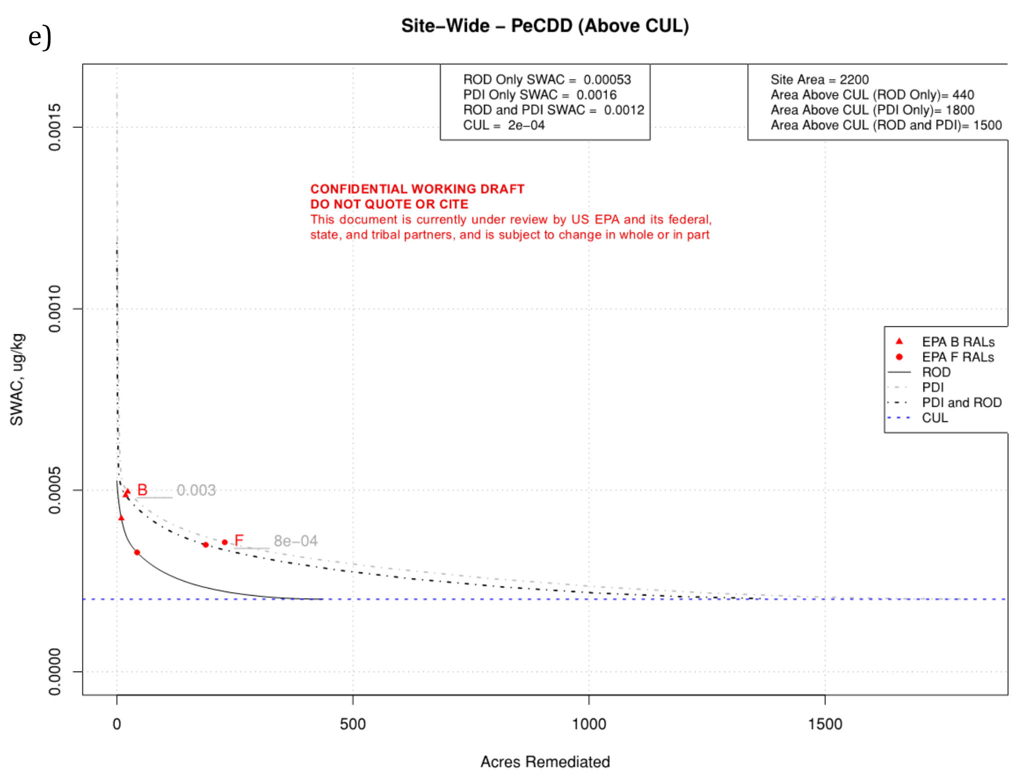
EPA B RALs
EPA F RALs
ROD
PDI
PDI and ROD
CUL
B
0.002
F
6e–04
SWAC, ug/kg
Acres Remediated

e)


Site–Wide – PeCDD (Above CUL)
ROD Only SWAC = 0.00053
PDI Only SWAC = 0.0016
ROD and PDI SWAC = 0.0012
CUL = 2e–04
Site Area = 2200
Area Above CUL (ROD Only)= 440
Area Above CUL (PDI Only)= 1800
Area Above CUL (ROD and PDI)= 1500
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This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part
EPA B RALs
EPA F RALs
ROD
PDI
PDI and ROD
CUL
B
0.003
F
8e–04
SWAC, ug/kg
Acres Remediated

f)

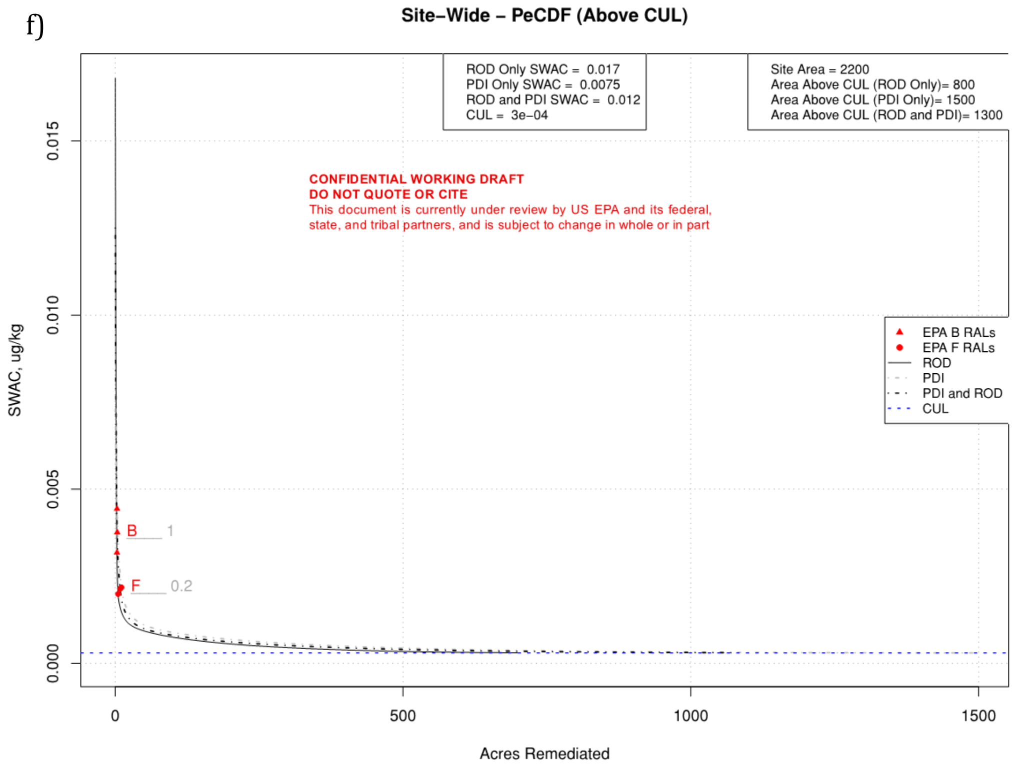


Figure 3. RAL curves for the six focused COCs a) total PCBs; b) total PAHs; c) DDx; d) 2,3,7,8-TCDD; e) 1,2,3,7,8-PeCDD; and f) 2,3,4,7,8-PeCDF. The figures show RAL curves for the RI/FS data (ROD), 2018 PDI data (PDI), and combined datasets (PDI and ROD). The navigation channel (i.e., B) and Site-wide (i.e., F) RALs are shown as red triangles and circles, respectively.

The updated plots with the 2018 PDI data show that the RAL concentrations for the focused COCs selected in the ROD[1] are still appropriate. The curves for total PAHs, DDx, and PeCDF indicate little change while those for TCDD and PeCDD show an increase in the area requiring active remediation. The area requiring active remediation for total PCBs appears to have decreased; however, the F RAL is still appropriate for substantial risk reduction in the nearshore areas without experiencing diminishing returns. The curves for the three datasets (ROD; PDI; ROD and PDI) are generally similar but do contain differences. These differences are due to the 10-15 years between the ROD and PDI data collection and a more complete Site-wide sampling for dioxins/furans performed in 2018.

[1] The Proposed Explanation of Significant Differences (ESD) proposes increasing the Site-wide RAL for total PAHs from 13,000 µg/kg to 30,000 µg/kg based on updated risk and toxicity information in the EPA Integrated Risk Information System.

Summary and Conclusions

Seventy percent of the ROD SMAs are erosional, neutral or in dynamic equilibrium compared with 44% of the remaining Site area. Therefore, MNR will not sufficiently reduce risk in the SMAs where active remediation is required. The PDI data indicate that the RALs selected in the ROD are still appropriate and for natural recovery to be effective these hot spot areas need to be remediated. It is necessary to proceed into remedial design and remedial action to remediate these areas.

References

EPA. 2017. *Record of Decision.* Portland Harbor Superfund Site, Portland, Oregon. U.S. Environmental Protection Agency Region 10, Seattle, Washington. January.

EPA. 2016. *Portland Harbor RI/FS, Feasibility Study.* U.S. Environmental Protection Agency Region 10, Seattle, Washington. June.

cc: Davis Zhen
Eva DeMaria
Josie Clark
Hunter Young
Karl Gustavson
Cami Grandinetti

DELIBERATIVE-DRAFT Memorandum

To: *Sean Sheldrake, United States Environmental Protection Agency Region 10*

From: *CDM Smith*

Date: *April 15, 2019*

Subject: *Rounds 1 and 2 Upstream Sediment Trap Analysis and Willamette River Hydrodynamics*

Introduction

Upstream sediment trap deployments included four traps deployed across two transects, located at river miles (RM) 11.8 and 16.2 (shown with yellow circles in **Figure 1**). Each transect had a sediment trap deployed on the east and west side of the river. The Pre-Design Investigation (PDI) sediment trap results assist in understanding the contaminants of concern (COC) concentrations and qualitative spatial distribution of settleable suspended sediments upstream of the Portland Harbor Superfund Site (Site).

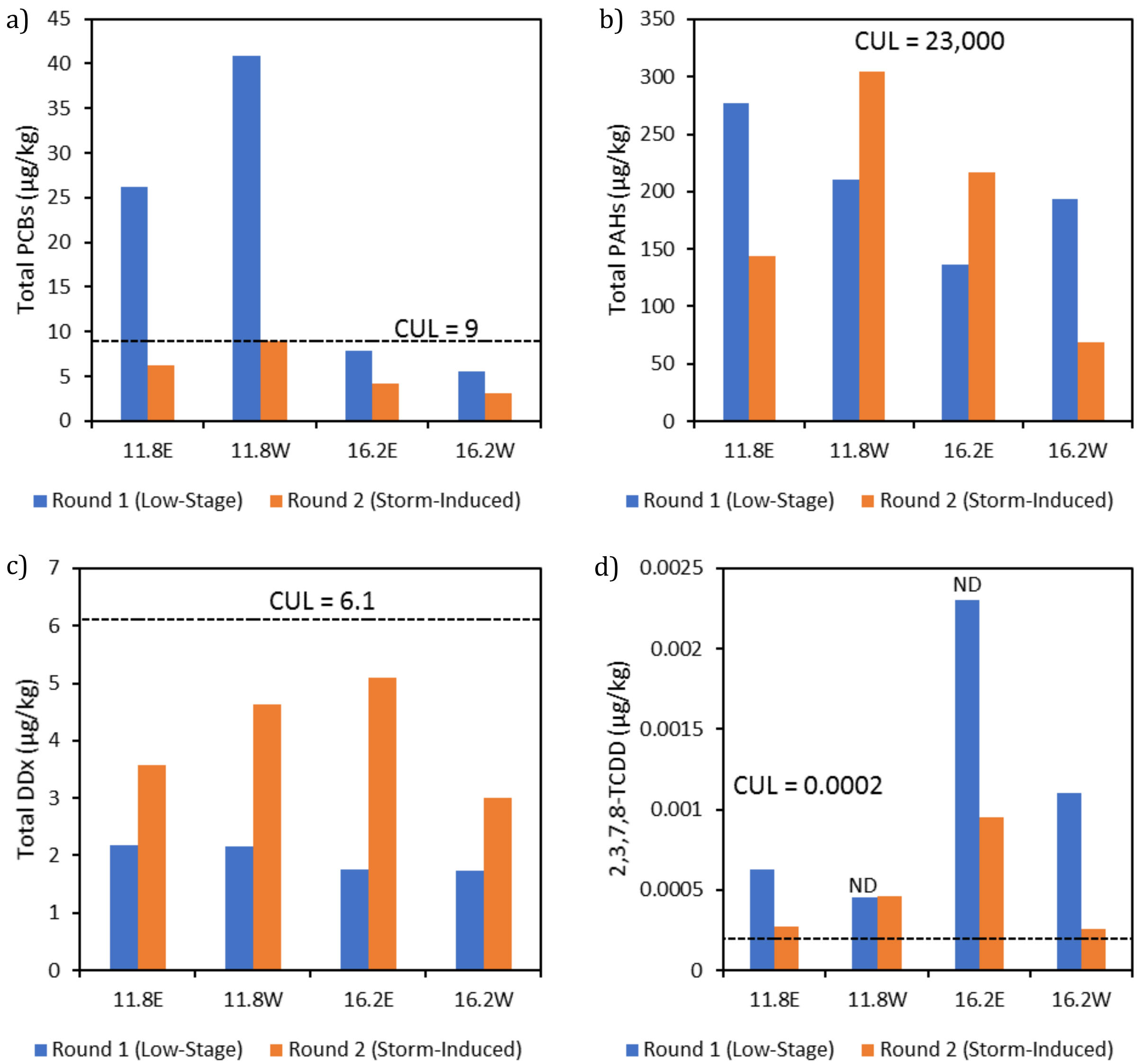
Figure 1. Upstream sediment trap locations from the PDI (yellow circles) deployed in the Willamette River.

Sediment Trap Chemical Results

Sediment trap data are currently available from the Rounds 1 and 2 samples:

- Round 1: Aug 16-Oct 31, 2018 (76 days)
    - Low-stage deployment
- Round 2: Oct 30, 2018 – Jan 30, 2019 (92 days)
    - Storm-induced flows deployment

Figures 2a through **2f** summarize the sediment trap results for the focused COCs from the Round 1 (low-stage) and Round 2 (storm-induced) deployments. Sediment trap COC concentrations were less than cleanup levels (CULs) at both transects during both deployments for total PAHs and DDx. Results for total PCBs were above CULs at RM 11.8 during the low-stage deployment but were otherwise less than CULs. All results for the dioxins/furans (2,3,7,8-TCDD; 1,2,3,7,8-PeCDD; and 2,3,4,7,8-PeCDF) were above CULs at RM 11.8 and 16.2 for both sampling rounds. However, 75% of the results from the low-stage deployment were not detected due to elevated detection limits (greater than CULs) at the analytical lab. Therefore, these non-detect results for the three dioxins/furans are shown at the lab-reported detection limits and may not be accurate estimates of actual concentrations. Dioxin/furan results from the storm-induced flows deployment were all detected and generally had lower concentration than the low-stage deployment.



e) f)

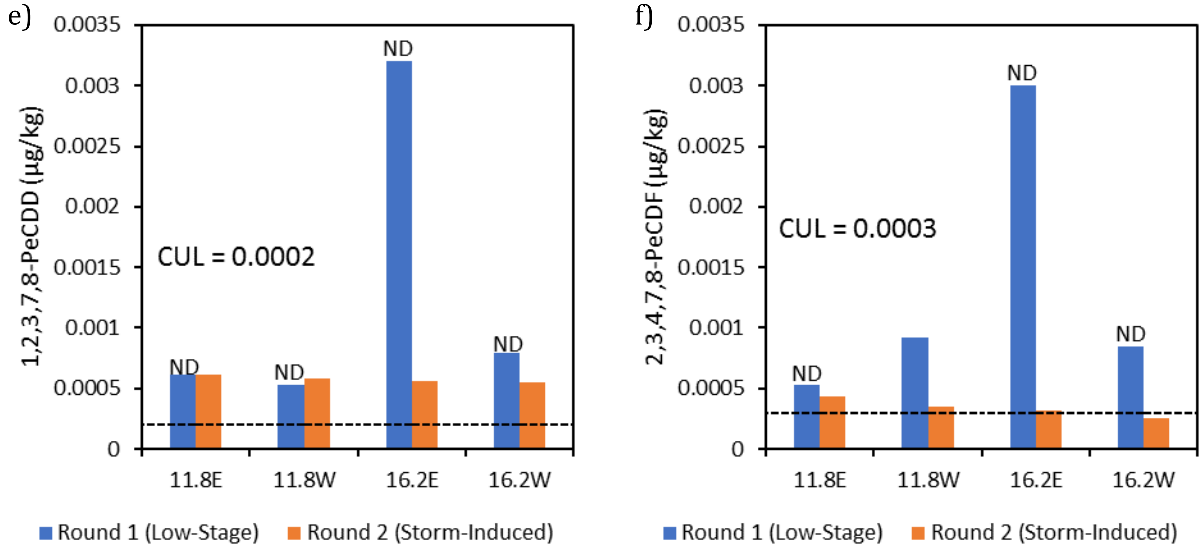


Figure 2. Rounds 1 (low-stage) and 2 (storm-induced) sediment trap results for a) total PCBs, b) total PAHs, c) DDx, d) TCDD, e) PeCDD, and f) PeCDF compared against ROD Table 17 CULs. ND = not detected

Hydrodynamics

Hydrodynamics play a role in the movement of suspended sediments. Flow reversals from tidal action cause water flow to oscillate upstream and downstream, potentially holding contaminated sediment within an area, or even causing it to distribute upstream. The Willamette River experiences tidally-induced flow reversals during low-water conditions, which typically occur during late summer and fall. The Round 1 deployment occurred during low river stage with lower average discharge and more frequent flow reversals. Round 2 occurred during the period of winter storms, with fewer flow reversals and higher average discharge. **Table 1** details flow reversal data and **Figures 3a** and **3b** show the discharge over time during the two deployment periods.

Table 1. Sample round deployment windows and corresponding hydrodynamic information.

Sediment Trap Deployment	Deployment Dates	Duration of Deployment	Number of Days with Flow Reversals	Average Discharge (cfs)	Largest Flow Reversal Discharge (cfs) and Date Recorded
Round 1 (low-stage)	Aug 16 – Oct 31, 2018	76 days	76 days	6846.45	-61400 (9/10/18)
Round 2 (storm-induced)	Oct 30, 2018 – Jan 30, 2019	92 days	54 days	27784.49	-56400 (11/22/18)

Note: cfs = cubic feet per second

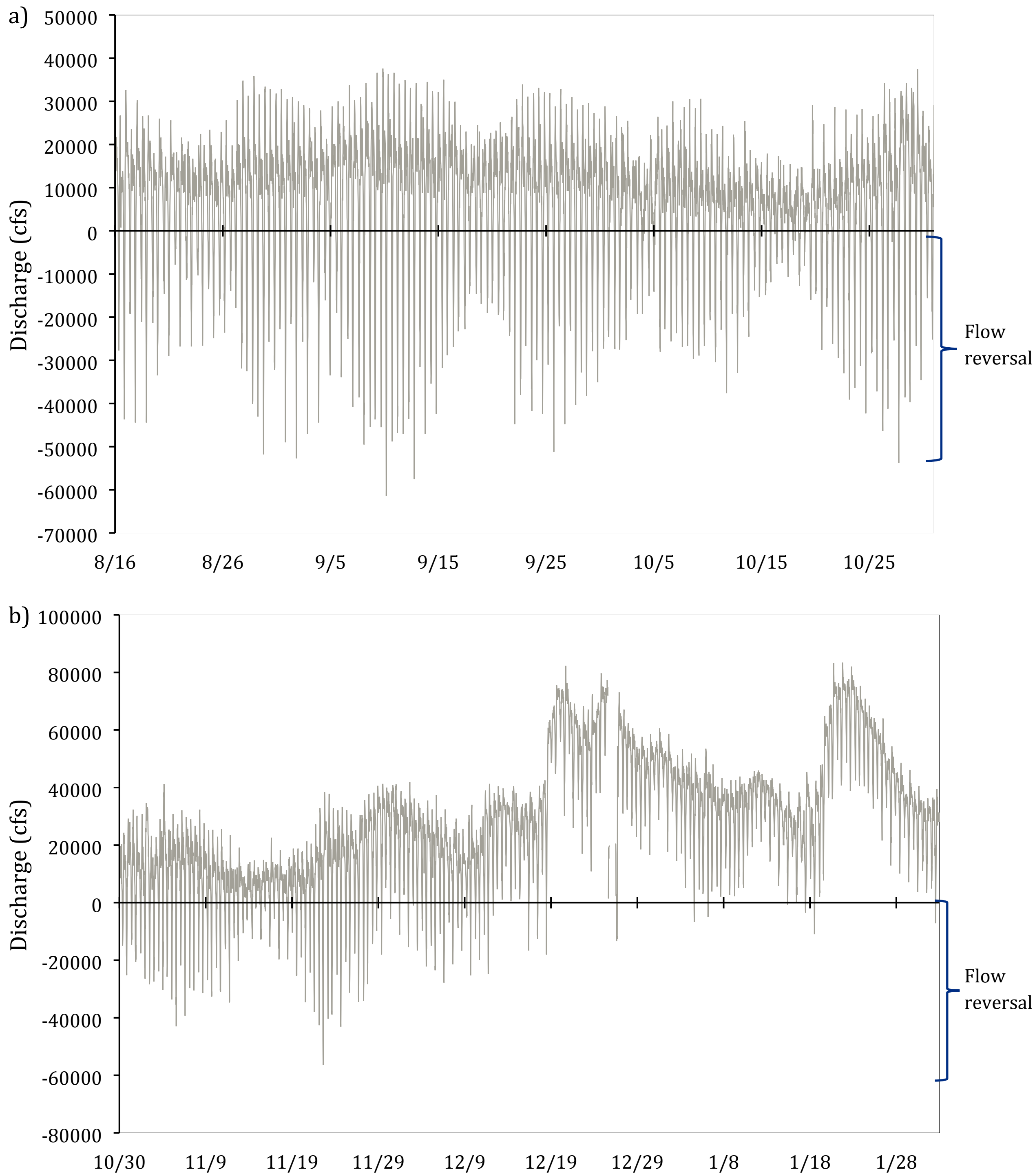


Figure 3. Willamette River discharge from the USGS gage at the Morrison Bridge (RM 13.5) during the a) Round 1 (low-stage) and b) Round 2 (storm-induced) sediment trap deployments. Negative discharge values signify periods of flow reversals.

Figures 3a and **3b** indicate that the low-stage deployment was subject to more frequent and higher magnitude flow reversals than the storm-induced flows deployment. Also, the RM 11.8 project area has numerous ship berths and experiences its highest levels of ship and barge traffic during summer and early fall when the Willamette River flows are lowest. This area has elevated PCB concentrations and a high potential for resuspension due to tugs and propwash. Therefore, it is possible that the elevated PCB concentrations in the sediment traps deployed at RM 11.8 during the low-stage deployment result from local contamination. Further evidence for this is seen in the PCB concentration results at RM 11.8 which decreased during the Round 2 deployment, likely due to less shipping activity and higher flows reflecting more predominant upstream background PCB concentrations rather than a backwash influence from local elevated source contamination.

River turbidity increased in Round 2 with increased discharge and runoff from winter storms. The increased turbidity in Round 2 does not appear to have an overall impact on the focused COC sediment trap chemistry, except for DDx. Due to its previous widespread use as a pesticide, DDT and its derivatives (i.e., DDx) are present throughout the Willamette River watershed and were mobilized by higher flows during Round 2. This is reflected by the higher concentrations for DDx in the Round 2 sediment trap results at both transects compared to Round 1. However, DDx results were still below CULs despite the slight increase from Round 1 to Round 2. **Figure 4** shows the relationship between discharge and turbidity from August 16, 2018 to January 30, 2019.

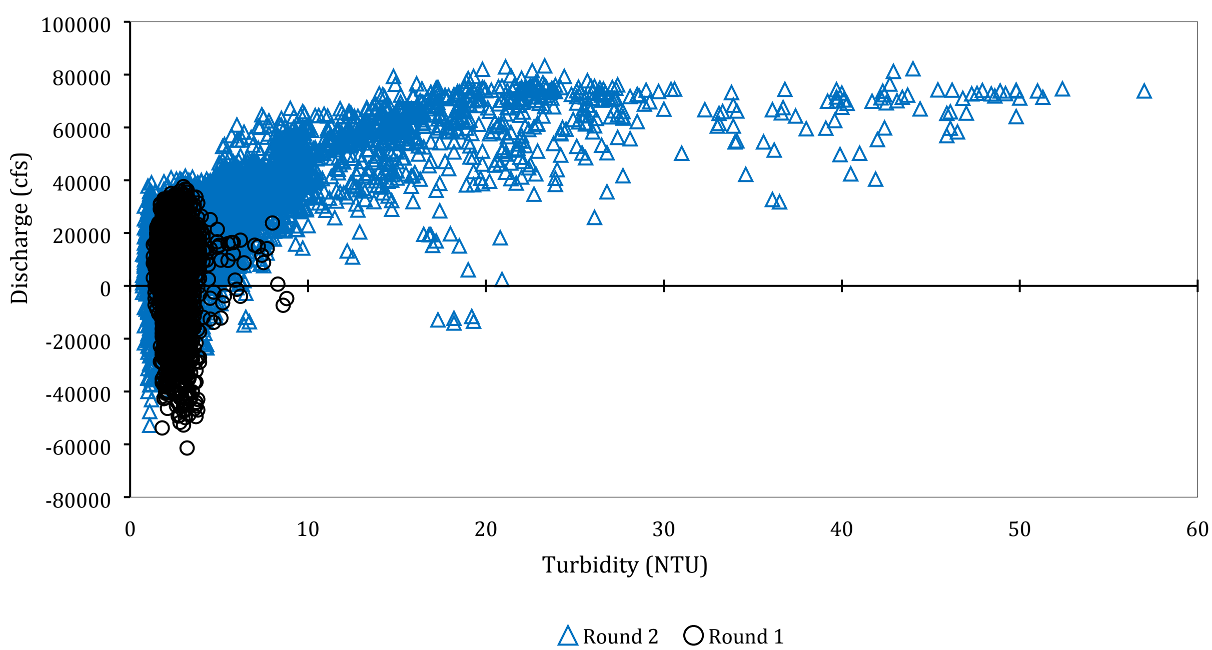


Figure 4. River discharge plotted against turbidity during both sediment trap deployments.

The estimated flux of suspended sediment during the two deployment periods is shown on **Figure 5**. Despite the increased turbidity measured during the Round 2 deployment, the estimated sediment flux at RM 11.8 was roughly the same for both deployments. RM 11.8 is a constriction in the channel width, which may be preventing suspended sediments from settling into the traps during the higher flows. The estimated sediment flux at RM 16.2 appears to have increased from Round 1 to Round 2, which is consistent with the higher turbidity measured during Round 2.

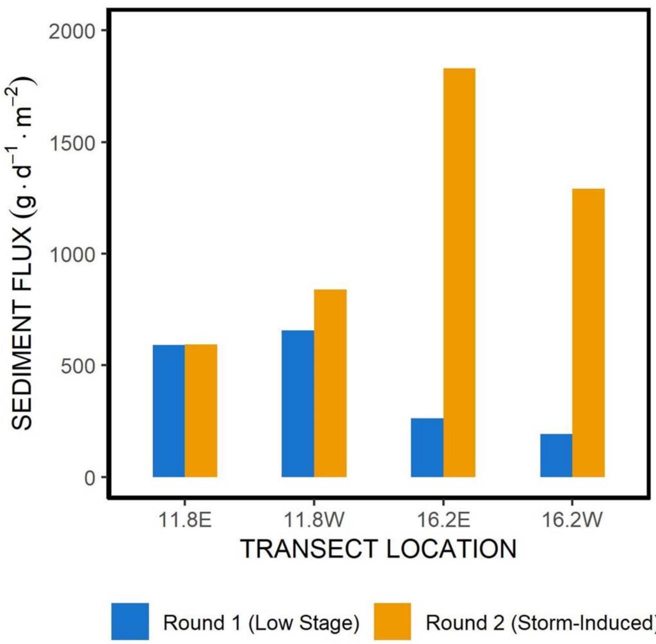


Figure 5. Estimated sediment flux for the Round 1 and Round 2 sediment trap deployments.

Summary and Conclusions

Flow reversals during the low-stage deployment suggest that PCB concentrations at RM 11.8 are due to local contamination rather than an upstream source. The three dioxins/furans were above CULs during both sampling rounds; however, the large percentage of non-detect samples during the low-stage deployment make it difficult to draw any meaningful conclusions from these results. The two deployments currently completed suggest that upstream suspended sediments are relatively clean and do not represent an uncontrolled source of contamination.

cc: Davis Zhen
Hunter Young
Eva DeMaria
Josie Clark
Cami Grandinetti

DELIBERATIVE-DRAFT Memorandum

To: *Sean Sheldrake, United States Environmental Protection Agency Region 10*

From: *CDM Smith*

Date: *April 19, 2019*

Subject: *Subsurface Modeling Evaluation and Sediment Management Area Delineation*

Introduction

Sediment management areas (SMAs) depicted in the Portland Harbor Superfund Site (Site) Record of Decision (ROD) were developed using chemical data only from the surface sediment (top 0-30 centimeters [cm]) due to the limited number of subsurface sediment cores collected during the Remedial Investigation (RI) and Feasibility Study (FS) (EPA 2016, 2017). While the existing subsurface core data is limited in significant areas of the Site for completing remedial design, additional sediment data in both the surface and subsurface have been collected since the RI/FS database was finalized. These data, in addition to the RI/FS cores, have been incorporated into a Site-wide subsurface sediment model. This new model will be used to support many components of remedial design decisions including:

- Identify areas where higher density subsurface sediment core sampling is needed to horizontally and vertically bound areas of contamination
- Estimate volumes of contaminated sediments in SMA areas to generate more accurate disposal costs
- Explore how SMA areas change over time with new bathymetry surveys and additional sediment samples

This model will be continually updated as new subsurface data are collected throughout the Site.

Subsurface Sediment Model Development

The subsurface sediment model has been developed using a three-dimensional (3-D) geological modeling software program called Leapfrog Works (v2.2.2) developed by Seequent. Leapfrog Works uses sample locations, chemistry data, and mathematical interpolations to develop 3-D estimates of areas of interest.

For Portland Harbor, sediment samples from the RI/FS database, River Mile (RM) 11E Supplemental RI/FS (GSI 2014), and 2018 Pre-Design Investigation (PDI) have currently been incorporated into the 3-D model. As new remedial design samples are collected the model will be updated to include this new information.

Sediment sample locations throughout the Site were draped over the 2018 bathymetric surface (i.e., river bottom elevations) to accurately place them in 3-D space. From there, concentrations of the ROD Table 21 contaminants of concern (COCs) were evaluated to determine if they were greater than the applicable remedial action level (RAL) and/or principal threat waste (PTW) threshold. A 3-D field of interpolated sediment concentrations for the Table 21 COCs was developed and the union of the individual COC exceedances of RALs and/or PTW thresholds were mapped as subsurface SMAs. **Figure 1** shows the lateral extent (i.e., two dimensions) of the modeled subsurface SMAs compared to the ROD SMAs (surface sediment only).

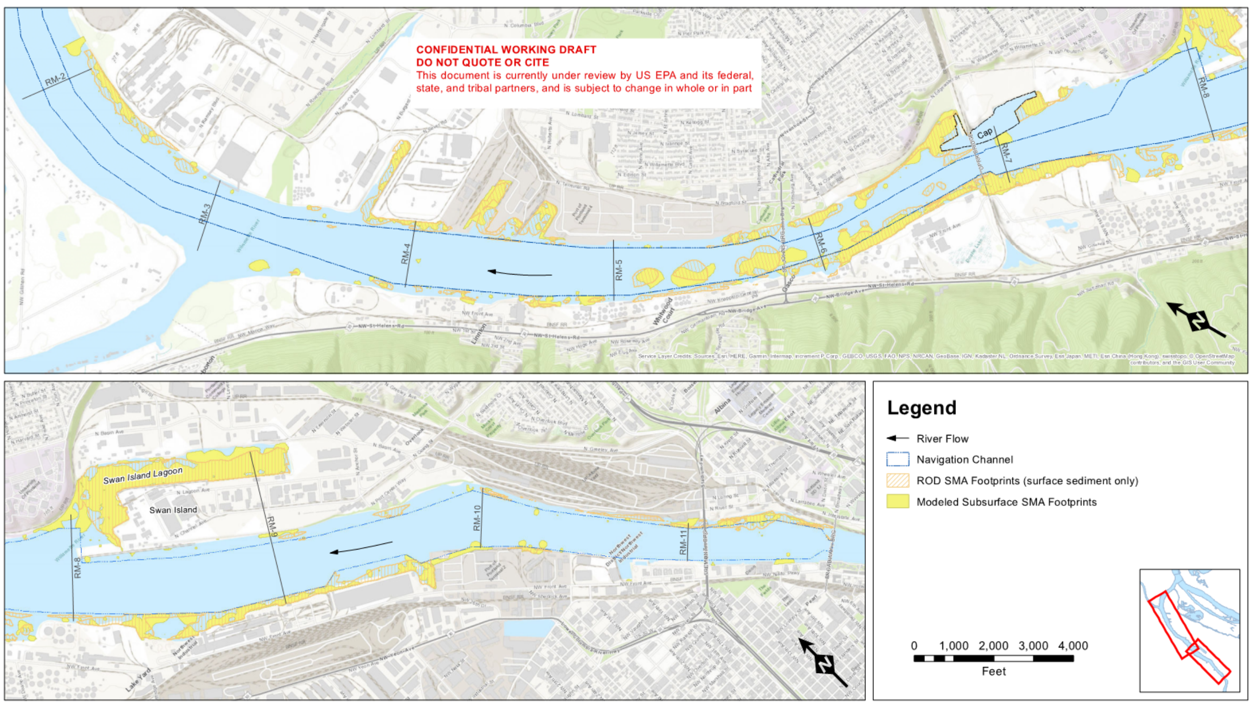


Figure 1. Site-wide map of the modeled subsurface SMA footprints compared to the ROD SMA footprints (surface sediment only).

Figure 1 shows that the majority of the modeled subsurface SMA footprints are encompassed by the ROD surface-only SMA footprints. However, there are some areas where subsurface contamination is estimated to be present where the surface (top 0-30cm) may not contain RAL or PTW exceedances. This is consistent with the conceptual site model (CSM) in the ROD where clean sediment may be depositing in areas of subsurface contamination. These estimated areas of subsurface contamination should be further evaluated in remedial design. **Supplemental Figure S1** shows the modeled subsurface SMA areas on a smaller spatial scale.

Current Applications

The 3-D sediment model has already been used to identify subsurface sediment RAL exceedances outside of the Pre-RD Group's preliminary refined PDI surface-only SMA footprint area. This analysis was conducted throughout the Site, and **Figure 2** shows how the modeled subsurface SMAs were compared against the Pre-RD Group's surface-only SMAs in an area.

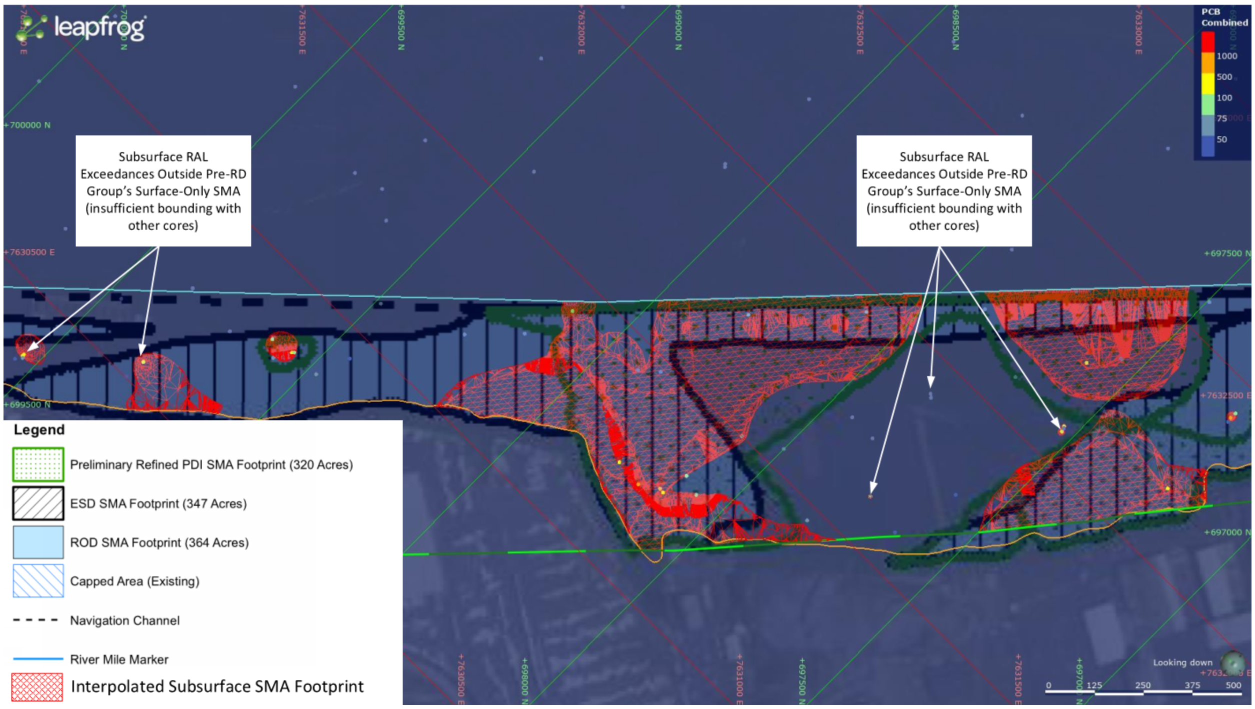


Figure 2. Annotated map showing subsurface sediment RAL exceedances outside of the Pre-RD Group's preliminary refined PDI surface-only SMA footprints. Map shows the area from approximately RM 8W to 8.5W.

Multiple instances of insufficiently bounded subsurface sediment cores with RAL exceedances outside of the Pre-RD Group's SMAs were identified. These areas need to be explored during remedial design and the subsurface modeling is helping to identify where data gaps sampling is needed. The **Supplemental Figures** contain the annotated maps for the rest of the Site broken down by focus areas.

Additionally, the 3-D sediment model was used to identify the presence of PCBs, PAHs, and/or DDx in subsurface sediments in areas of dioxin/furan contamination in surface sediment. This analysis determined that dioxin/furan RAL exceedances in the surface sediments are collocated with the other focused COCs (PCBs, PAHs, and/or DDx) in the subsurface. These findings were summarized in a previous memo (CDM Smith 2019). The **Supplemental Figures** contains the map identifying the areas where surface sediment dioxin/furan RAL exceedances are collocated with the other focused COCs in the subsurface.

Summary and Conclusions

The 3-D sediment model is a useful tool that can be used during remedial design to better understand the areas of contamination, estimate volumes (and therefore cost) of contaminated sediment disposal, and truth-check design plans on smaller spatial scales. The model will be continually updated with new data as they are collected and will evolve and inform throughout the remedial design process.

References

CDM Smith. 2019. *Subsurface Sediment RAL Exceedances in Areas of Dioxin/Furan Surface Contamination*. Prepared for U.S. Environmental Protection Agency Region 10, Seattle, Washington. March 21.

EPA. 2017. *Record of Decision.* Portland Harbor Superfund Site, Portland, Oregon. United States Environmental Protection Agency Region 10, Seattle, Washington. January.

EPA. 2016. *Portland Harbor RI/FS, Feasibility Study.* U.S. Environmental Protection Agency Region 10, Seattle, Washington, June.

GSI Water Solutions, Inc. 2014. *Final Supplemental Remedial Investigation/Feasibility Study Field Sampling and Data Report, River Mile 11 East, Portland, Oregon.* Prepared for RM11E Group. September.

cc: Davis Zhen
Hunter Young
Eva DeMaria
Josie Clark
Cami Grandinetti
Karl Gustavson

DELIBERATIVE-DRAFT Memorandum

To: Sean Sheldrake, United States Environmental Protection Agency Region 10

From: CDM Smith

Date: May 3, 2019

Subject: Surface Water Rounds 1 and 2 Evaluation

Introduction

Surface water sampling consisted of three sampling rounds at seven transects located within the Portland Harbor Superfund Site (Site), Multnomah Channel (MC), and the Downtown Reach and Upriver Reach (referred to collectively as the D/U Reach). The transects were located at river miles (RM) 1.9, 3 (mouth of MC), 4, 7, 8.8, 11.8, and 16.2 and are shown on **Figure 1**. Samples were collected along the east shore, west shore, and in the navigation channel and were composited into a single sample at each transect. The Pre-Design Investigation (PDI) surface water results assist in understanding the contaminants of concern (COC) concentrations and estimated spatial distribution of COC mass loading to, within, and leaving the Site.

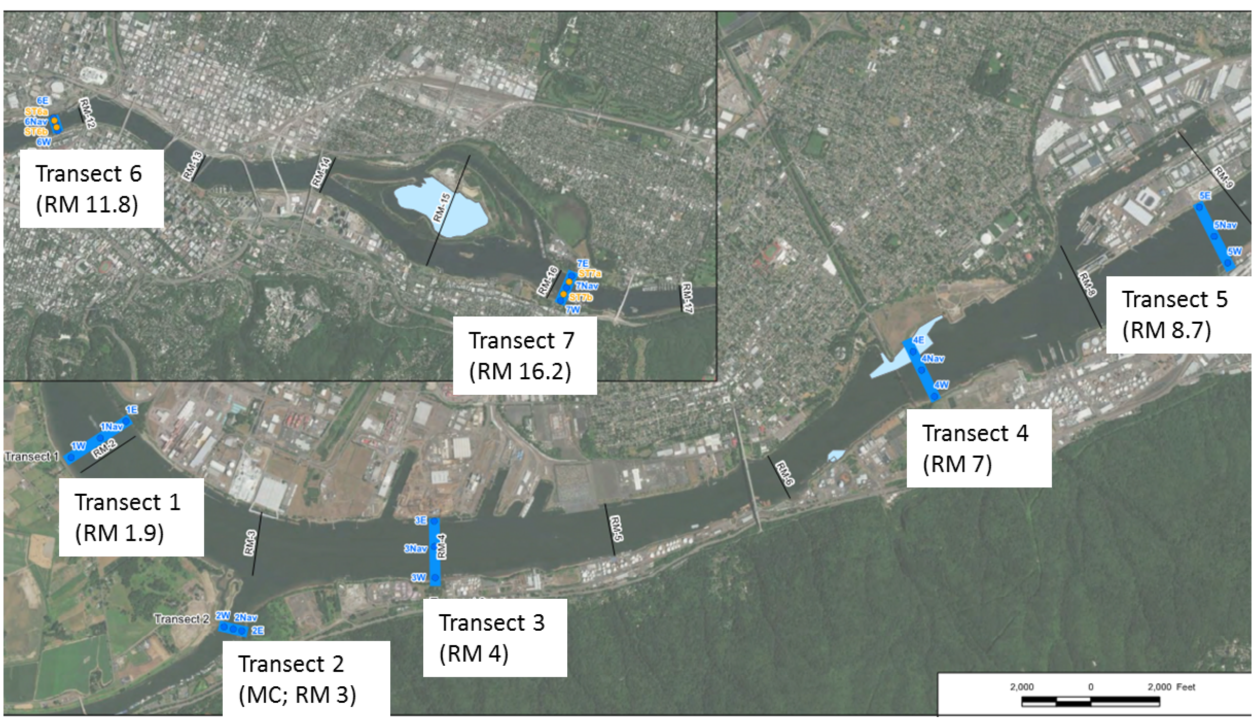


Figure 1. Map of the Site and D/U Reach showing the surface water sampling transects and their respective river miles.

Surface Water Chemistry Results

The surface water sampling targeted three different flow conditions: low river stage, stormwater flows, and high river stage. Chemistry data from the first two sampling rounds are currently available and are discussed in this memo. The three sampling rounds are summarized in **Table 1**, and **Figure 2** shows the Willamette River discharge from August 2018 through April 2019 when sampling occurred.

Table 1. Surface water sampling rounds and average discharge.

Sampling Round	Sampling Dates	Average Tidally-Filtered Discharge (cfs)	Occurrence of Flow Reversals During Sampling
Round 1 (low-stage)	August 20-25, 2018	6,285	Yes
Round 2 (stormwater)	November 27-December 1, 2018	23,560	Yes
Round 3 (high-stage)[1]	January 26-27 and February 17-18, 2019	50,300	No

Notes:
cfs – cubic feet per second
[1] EPA has not received the Round 3 chemistry data from the Pre-RD Group.

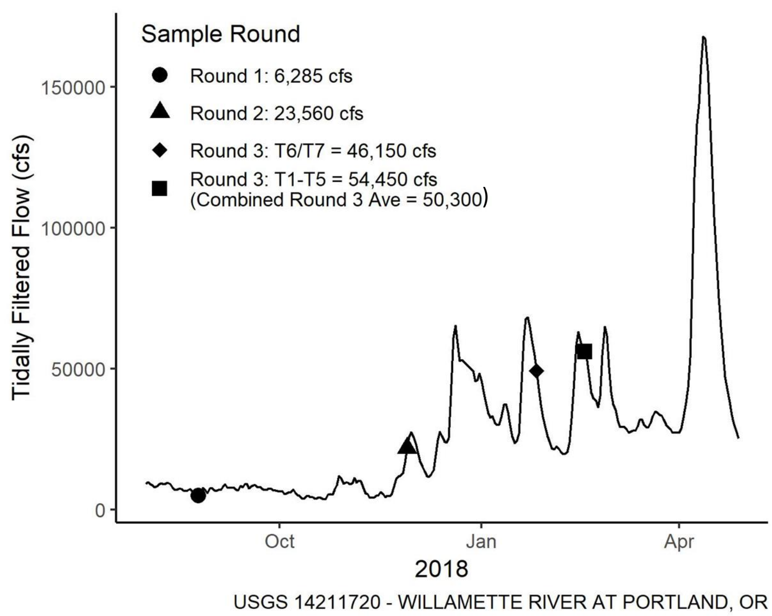


Figure 2. Tidally-filtered flow in the Willamette River from August 2018 through April 2019 at the Morrison Bridge (RM 13) in Portland, Oregon.

The surface water samples were collected as unfiltered (total) and filtered (dissolved) samples and were analyzed for the Record of Decision (ROD) Table 17 COCs. **Figure 3a** through **3d** summarize the surface water results from the seven transects for the focused COCs. Rounds 1 and 2 average concentrations show that PCBs, cPAHs, and total dioxins/furans (i.e., 2,3,7,8-TCDD eq) were above the cleanup levels (CULs) at all transects. These CULs were selected in the ROD based on existing regulatory requirements for human health criteria (U.S. Clean Water Act; Oregon Water Pollution Act) and represent very low concentrations.

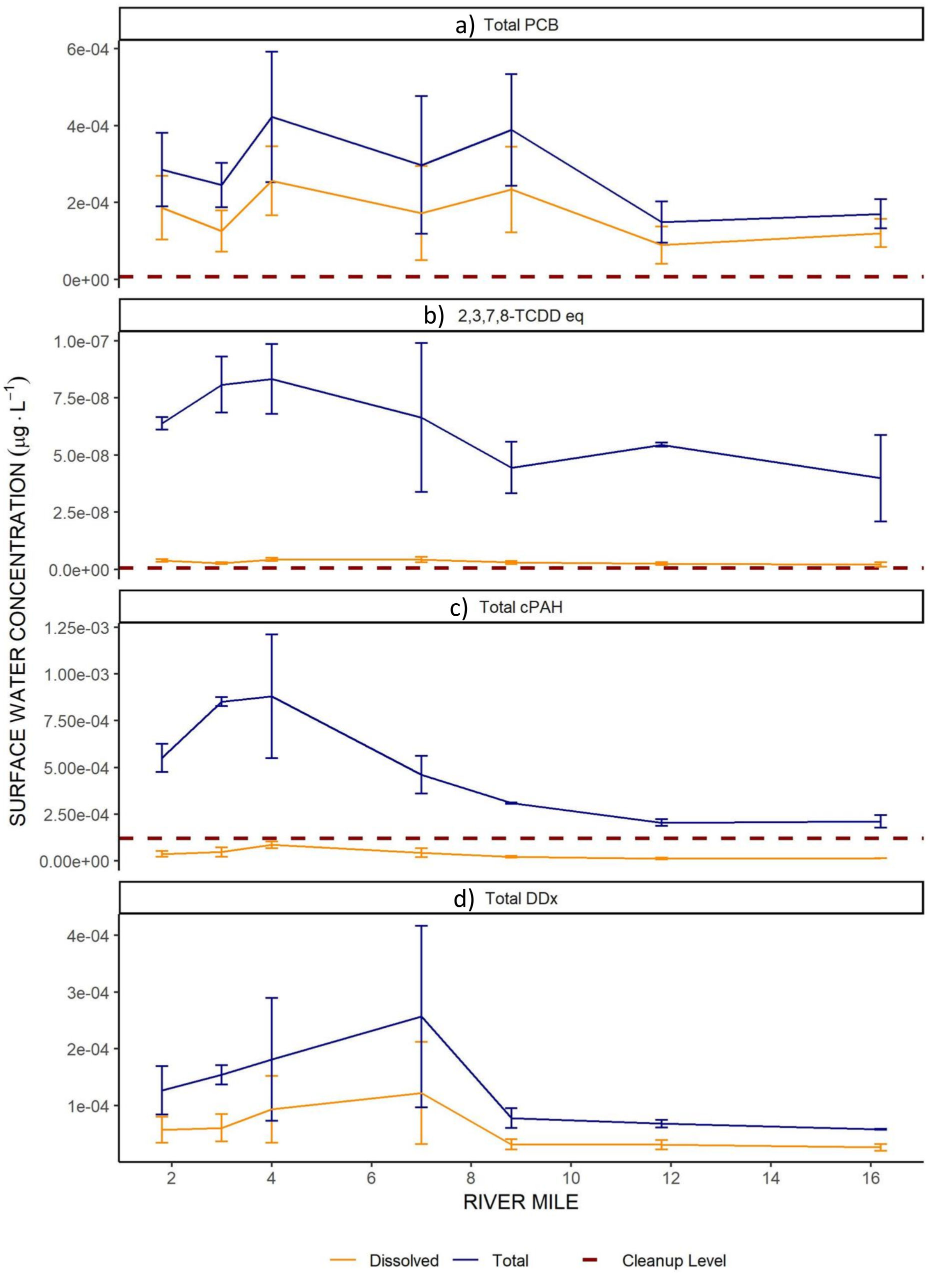


Figure 3. Average of Rounds 1 and 2 surface water concentrations of a) total PCBs, b) total dioxins/furans (i.e., 2,3,7,8-TCDD eq), c) cPAHs, and d) DDx at the seven transect locations compared against CULs.
Notes: Range bars shows range of results from Round 1 and Round 2 (n=2) at each transect. Chart is organized from downstream (left) to upstream (right). The CUL for DDx is not shown as it is much greater than the measured concentrations.

Additionally, the highest COC concentrations measured were generally located immediately downstream of areas of known sediment contamination. For example, PCBs were highest at Transects 3 and 5 which are downstream of PCB sediment contamination at Terminal 4/Schnitzer Steel (RM 4) and Gunderson (RM 9), respectively. This pattern was consistent for cPAHs (Transect 3; Gasco and other oil companies), DDx (Transect 4; Arkema), and total dioxins/furans (Transects 3 and 4; Terminal 4 and Arkema, respectively). While the concentrations of DDx were below its risk-based CULs at all transects, the compounds that comprise the total DDx sum (DDD, DDE, and DDT) have much lower regulatory-based CULs than DDx and were above their respective CULs in the Site (see **Supplemental Data Figures**).

Surface water concentrations were also compared between the different reaches. **Figures 4a** through **4d** show the average concentrations for the Site (Transects 1 through 5) and upstream D/U Reach (Transects 6 and 7).

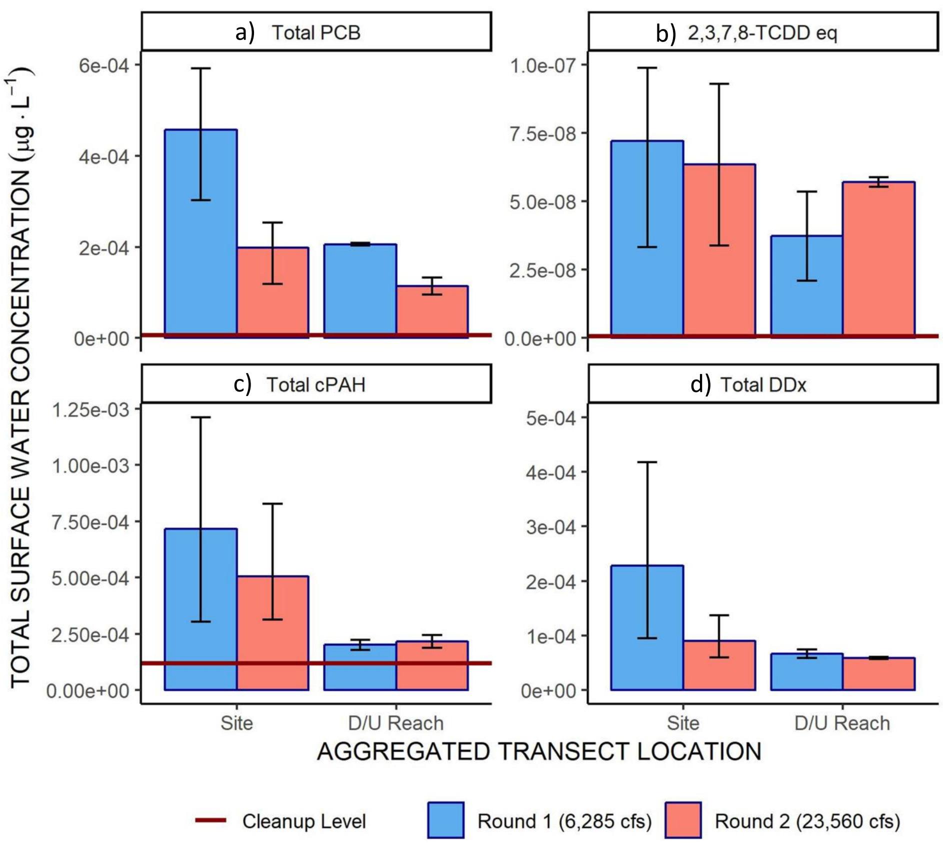


Figure 4. Rounds 1 (low-stage) and 2 (stormwater) surface water average concentrations for a) total PCBs, b) total dioxins/furans, c) cPAHs, and d) DDx compared against ROD Table 17 CULs.
Notes: Range bars shows range of results from the Site (Transects 1-5; n=5) and D/U Reach (Transects 6 and 7; n=2) during Round 1 and Round 2. The CUL for DDx is not shown as it is much greater than the measured concentrations.

Average concentrations were higher in the Site than in the D/U Reach for both Rounds 1 and 2 for PCBs, cPAHs, and DDx while concentrations of total dioxins/furans were more similar between the

Site and D/U Reach. Additionally, the focused COC concentrations were higher during Round 1 than in Round 2 in the Site while the D/U Reach exhibited smaller changes between sampling rounds. Plots including the average concentrations in the dissolved phase are included in the **Supplemental Data Figures**. An explanation for these patterns is provided in the following sections.

Willamette River Hydrodynamics

Hydrodynamics play a role in the movement of contaminants in both the particulate (i.e., suspended sediments) and dissolved phases. A detailed discussion of hydrodynamics as they pertain to the Rounds 1 and 2 sediment trap results is included in a previous memo (CDM Smith 2019b).

Despite the four-fold increase in average discharge from the Round 1 to the Round 2 surface water sampling events, the turbidity measured at each transect was slightly lower during Round 2. This could possibly be due to brown algae present in the Willamette River, which blooms during the summer and can be detected by optical turbidimeters like the one used during the PDI surface water sampling. Frequent filter changes and higher chlorophyll measurements in Round 1 versus Round 2 provide additional lines of evidence for the impact of algae on the measured turbidity. Additionally, the storm that was targeted in Round 2 was a low magnitude storm event (**Figure 2**) that would not increase turbidity as dramatically as a larger storm or sustained higher flows. The similarities in turbidity between the Rounds 1 and 2 sampling along with the higher flows during Round 2 could be having a dilution effect on the COC mass leading to the lower concentrations observed. Therefore, the results from the Round 3 (high-stage) sampling, which had an average flow double that of Round 2 and will likely have much higher measured turbidity, will provide essential information to better understand the dynamics of COC concentrations and mass loading to the Site.

Contaminant Mass Loading

Figure 3 and the **Supplemental Data Figures** show that roughly 50% of the contaminant mass is bound to suspended sediments and 50% is dissolved in the water column for PCBs and DDx while nearly all the mass is from suspended sediments for cPAHs and total dioxins/furans. All the COCs don't readily dissolve in water and instead bind strongly to sediment particles where they may be transported downstream or settle to the river bottom and accumulate in the tissues of fish and other aquatic organisms (ATSDR 2019).

The contaminant mass loading rates from the D/U Reach to the Site, within the Site, and leaving the Site were calculated for the focused COCs. The mass loading rate leaving the Site was calculated as the combined mass from Transect 1 (Willamette River mainstem) and Transect 2 (MC) following the 40%/60% split, respectively, determined during the Remedial Investigation (EPA 2016). **Figures 5a** through **5d** show the average focused COC mass loading rates for Rounds 1 and 2. The surface water mass loading entering and leaving the Site increased from Round 1 to Round 2 due to the four-fold increase in flow that occurred, while the loading rates within the Site were similar between the sampling rounds. Additionally, the loading rates were higher within and leaving the

Site than for the COC mass entering the Site, suggesting that there is more contamination present within the Site than there is upstream. This is consistent with the conceptual site model in the ROD and the 2018 PDI surface sediment data (EPA 2017; CDM Smith 2019a).

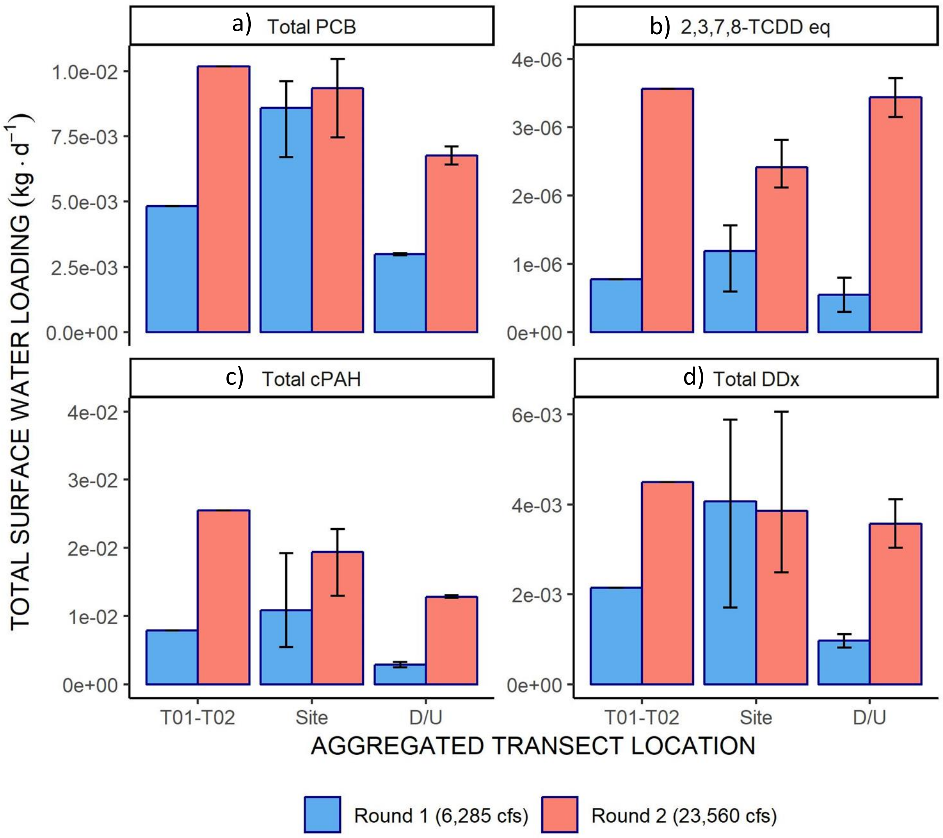


Figure 5. Rounds 1 (low-stage) and 2 (stormwater) surface water mass loading for a) total PCBs, b) total dioxins/furans, c) cPAHs, and d) DDx.
Notes: Mass loading leaving the Site was estimated using the combined loading from the Willamette River mainstem (T01) and Multnomah Channel (T02) transects. Range bars shows range of results within the Site (Transects 3, 4, and 5; n=3) and D/U Reach (Transects 6 and 7; n=2) during Round 1 and Round 2.

Total Dioxins/Furans

The upstream mass loading rates for total dioxins/furans increased from Round 1 to Round 2 with the Round 2 rates being greater than and roughly equivalent with those within and leaving the Site, respectively (**Figure 5b**). This along with the concentration results shown in **Figure 3b** suggests that surface water with dioxin/furan concentrations greater than the CUL are flowing into the Site from upstream with greater concentrations and loading rates at higher flows. However, the surface water CUL for total dioxins/furans is very low (5×10^{-10} µg/L or 0.5 parts per quintillion) and does not necessarily suggest that the suspended sediments in the water column have concentrations greater than the sediment CULs.

Summary and Conclusions

Surface water sampling results for Round 1 (low-stage) and Round 2 (stormwater) were above the very low, regulatory-based CULs for PCBs, cPAHs, and total dioxins/furans both in the Site and upstream. Concentrations in surface water and mass loading rates were highest near known hot spot areas of sediment contamination, suggesting that remediation of these areas along with ongoing source control will help in achieving CULs. Future repeated rounds of surface water sampling during and after construction of the remedy will allow for estimating long-term trends in COC concentrations and mass loading rates.

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cc: Davis Zhen
Hunter Young
Eva DeMaria
Josie Clark
Karl Gustavson
Cami Grandinetti

DELIBERATIVE-DRAFT Memorandum

To: *Sean Sheldrake, United States Environmental Protection Agency Region 10*

From: *CDM Smith*

Date: *May 3, 2019*

Subject: *Fish Tissue Statistical Evaluations*

Introduction

At the Portland Harbor Superfund Site (Site), different species of fish and shellfish are important food sources for subsistence and recreational fishers. Both non-resident (e.g., salmon) and resident (e.g., smallmouth bass) fish are caught in the Site and consumed by people living in the Portland area. The consumption of resident fish presents the greatest exposure risk to people from the Site contaminants of concern (COCs) (EPA 2017). Smallmouth bass specimens have been caught and analyzed for Site COCs during multiple studies and can be evaluated over time. This memo summarizes fish tissue results in smallmouth bass from the 2018 Pre-Design Investigation (PDI) and compares those data to data used in the Remedial Investigation (RI) (EPA 2016).

2018 PDI Fish Tissue Chemistry Results

During the 2018 PDI, smallmouth bass specimens were collected in the Site (n = 95), Downtown Reach (n = 21), and Upriver Reach (n = 19) and were analyzed for the Record of Decision (ROD) Table 17 fish tissue COCs. All smallmouth bass specimens had concentrations of total PCBs, DDx, and dioxins/furans greater than ROD Table 17 cleanup levels (CULs), except for 1,2,3,4,7,8-HxCDF. The **Supplemental Data Figures** attachment shows the smallmouth bass capture locations and their COC concentrations. Smallmouth bass specimens with the highest COC concentrations were generally collocated with elevated sediment concentrations. For example, smallmouth bass with the highest concentrations of total PCBs were collected from the sediment management areas (SMAs) of known PCB sediment contamination (Schnitzer Steel, Willamette Cove, Swan Island Lagoon, Gunderson, and RM 11E). This same pattern was consistent for DDx (Arkema) and dioxins/furans (Arkema, Willamette Cove, and Gunderson). Higher concentrations of these COCs in sediment lead to more bioaccumulation and higher levels in fish tissue.

Figures 1a though **1e** show the average concentrations for total PCBs, DDx, and three dioxins/furans (2,3,7,8-TCDD; 1,2,3,7,8-PeCDD; 2,3,4,7,8-PeCDF), respectively, compared against the risk-based CULs. These fish tissue COCs have very low CULs due to their carcinogenic and bioaccumulative properties; additionally, they are sediment focused COCs (EPA 2017).

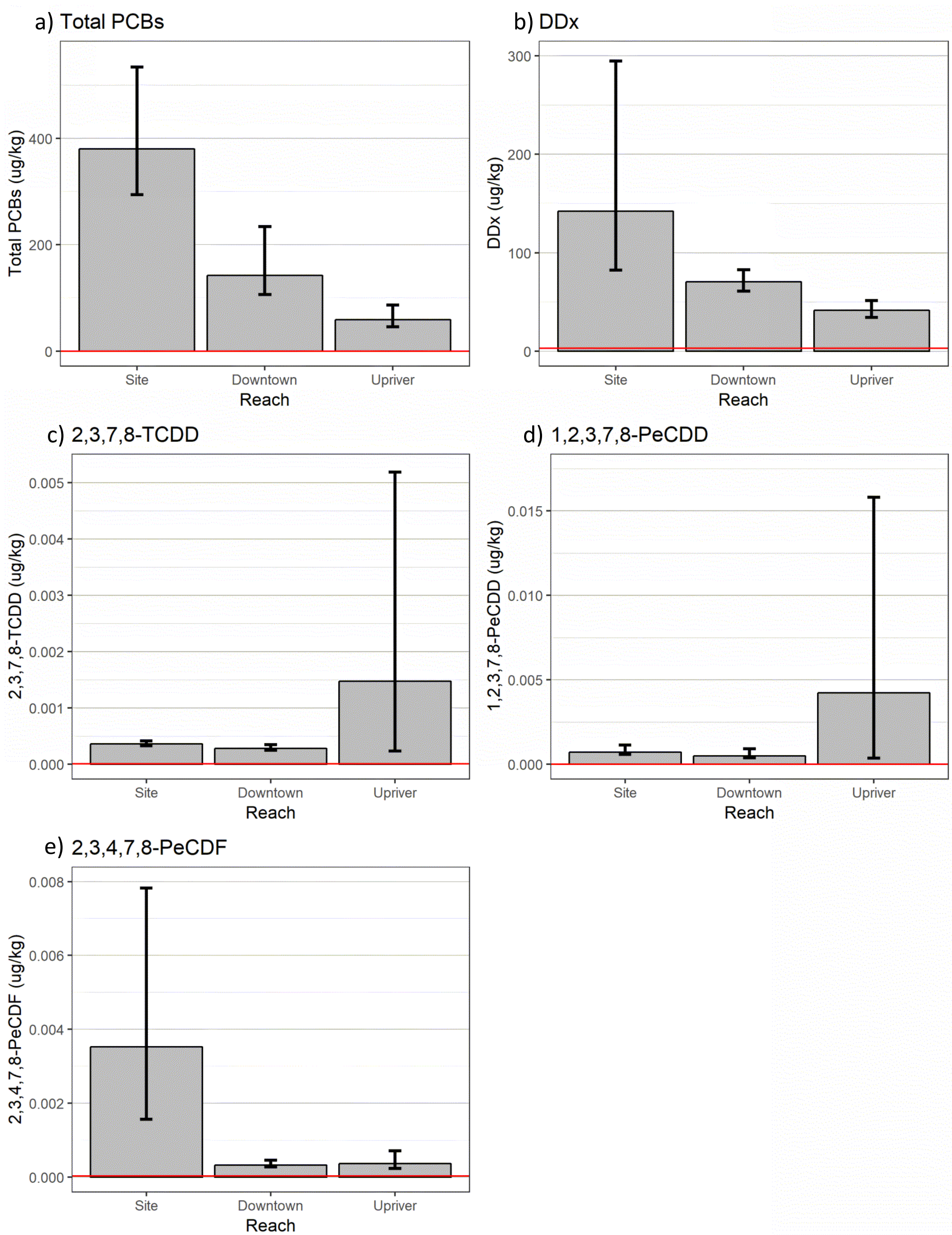


Figure 1. Average concentrations with 95 percent (%) confidence intervals for the fish tissue COCs: a) total PCBs; b) DDx; c) 2,3,7,8-TCDD; d) 1,2,3,7,8-PeCDD; and e) 2,3,4,7,8-PeCDF. The red line denotes the ROD Table 17 fish tissue CUL for each COC.

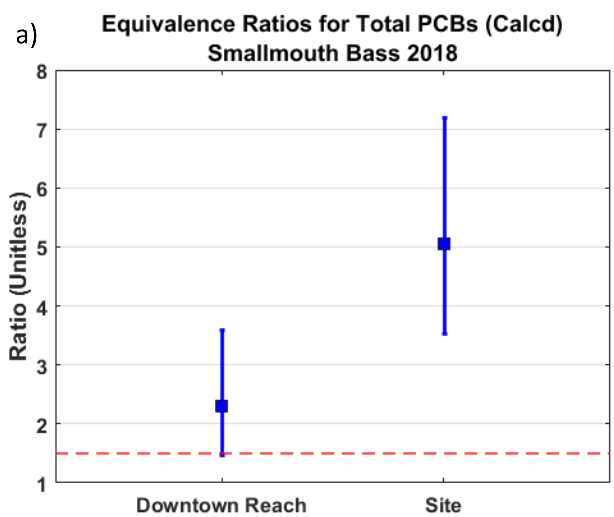
Average concentrations of total PCBs, DDx, and PeCDF were higher in the Site than in the Downtown Reach and Upriver Reach; average concentrations of TCDD and PeCDD were highest in the Upriver Reach. However, the Upriver Reach average for TCDD and PeCDD is elevated relative to the Site and Downtown Reach due to a single fish specimen that had the highest measured concentrations of these COCs during the 2018 PDI. When this high concentration fish is excluded, Upriver Reach average concentrations for TCDD and PeCDD are slightly less than the Site average. Currently, it is unclear why this single smallmouth bass specimen in the Upriver Reach has such high concentrations of TCDD and PeCDD.

Equivalence Testing

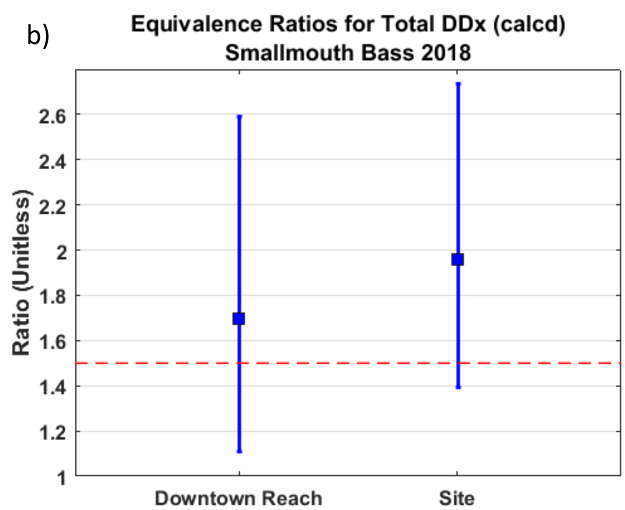
To evaluate remedial effectiveness before, during, and after the cleanup, fish tissue concentrations within the Site are compared to those in the Upriver Reach (i.e., background reference area). This comparison is called equivalence testing and is based on the ratio of the Site and Upriver Reach (along with the ratio of the Downtown Reach and Upriver Reach) geometric means. When the 95% upper confidence limit (UCL) for the ratio is less than 1.5, the Site (or Downtown Reach) and background reference area are deemed to be statistically equivalent and the remedy is achieving the intended goals.[1]

The equivalence testing was initially performed using the surface sediment data, which showed that PCBs, PAHs, DDx, and dioxins/furans in the Site are not equivalent with the Upriver Reach (CDM Smith 2019). The results of the fish tissue equivalence testing are similar to those of the surface sediment and are summarized in **Figures 2a** through **2e** for total PCBs, DDx, and three dioxins/furans (TCDD, PeCDD, and PeCDF), respectively. Additional fish tissue equivalence testing figures are included in the attached **Supplemental Data Figures**.

a)



b)



[1] The ratio of 1.5 for determining equivalence allows for uncertainty in the data and may be adjusted based on future statistical evaluations. Determination of whether the Site has reached equivalence with the Upriver Reach requires a series of repeated sampling events conducted as part of the long-term monitoring program.

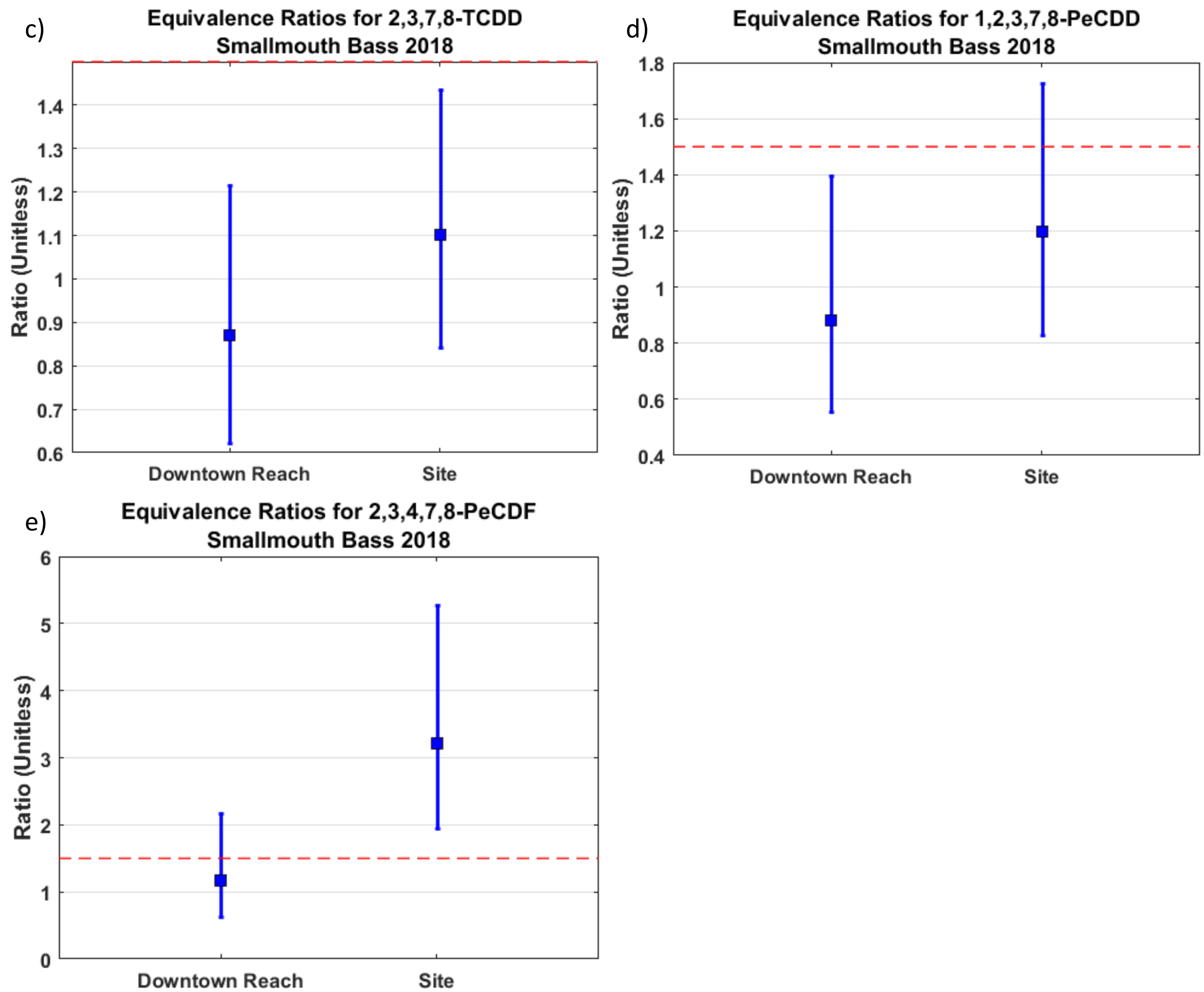


Figure 2. Ratio of the Site and Upriver Reach and the Downtown Reach and Upriver Reach geometric means for a) total PCBs, b) DDx, c) TCDD, d) PeCDD, and e) PeCDF. The red dashed line denotes the equivalence threshold at 1.5.

The equivalence testing suggests that the 2018 smallmouth bass tissue concentrations for total PCBs, DDx, PeCDD, and PeCDF in the Site are not equivalent with those in the Upriver Reach and are therefore statistically higher in the Site. TCDD concentrations in the Site appear to be equivalent with the Upriver Reach, but additional future sampling rounds are required to assess whether this trend is consistent over time. It is important to note that although TCDD concentrations in the Site are equivalent with the Upriver Reach, none of the samples were below the risk-based CUL.

Concentration Trend Analysis

Smallmouth bass sampling occurred in the Site and upstream in 2002, 2007, 2012, and 2018. These sampling events varied in the locations from which fish specimens were collected, which COCs were analyzed, and whether a sample result was from a single fish or multiple fish combined. The 2002 and 2007 sampling events during the RI obtained fish tissue data for all the Site COCs but had fewer results due to creating composite samples (n=17 for each study). The 2012 sampling event included more samples collected throughout the Site and upstream (n=92) and no compositing, but specimens were only analyzed for total PCBs. Sampling during the 2018 PDI had a large, well distributed sample size (n=135), and specimens were analyzed for all the ROD Table 17 COCs.

Despite the differences in the different sampling events, it is possible to evaluate how concentrations for the fish tissue COCs have changed from 2002 to 2018. A first order decay model was developed to estimate the average rates of change in units of per year (yr^{-1}). The model assumes a common rate for the Site but with differing absolute concentrations in different areas. Average rates of change for the Site were estimated for total PCBs, DDx, and the five dioxins/furans with fish tissue CULs, which are summarized in **Figure 3**.

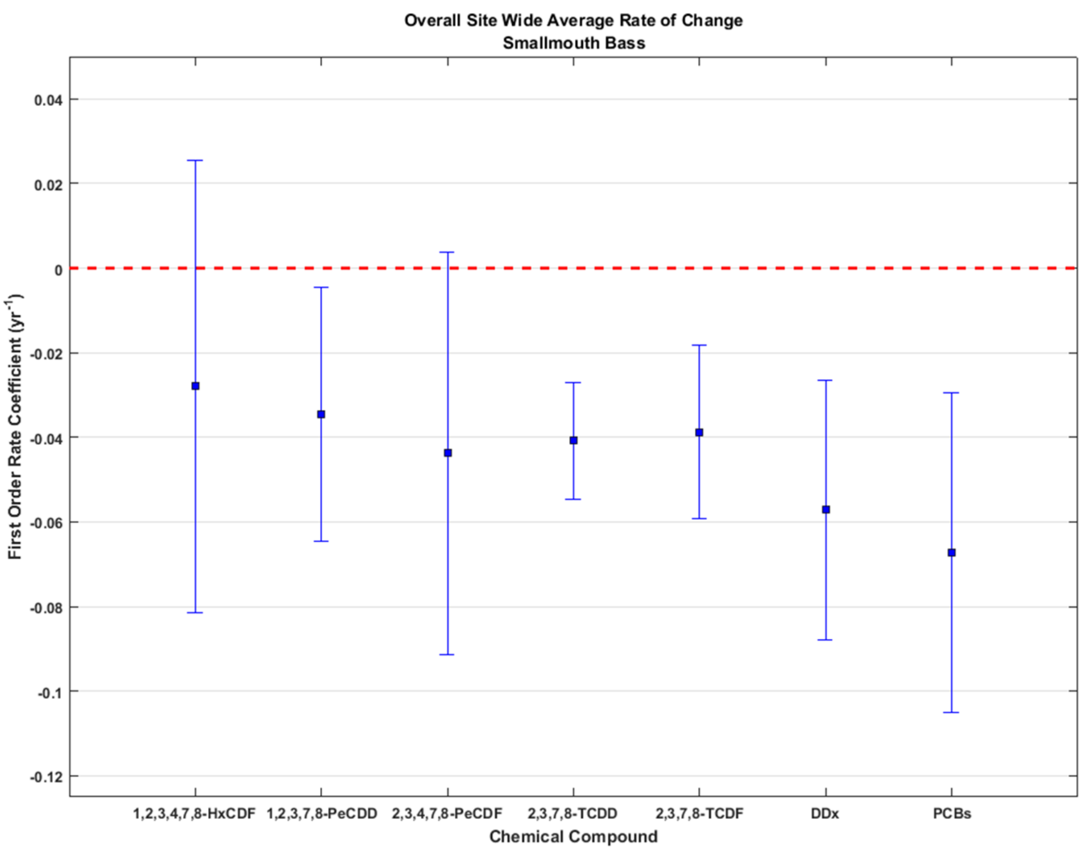


Figure 3. Overall Site-wide average rates of change (yr^{-1}) for total PCBs, DDx, and the five dioxins/furans with fish tissue CULs. Error bars that exclude the red dashed line at zero indicate rates of change that differ from zero statistically.

The trend analysis suggests that Site-wide fish tissue concentrations of PCBs, DDx, TCDD, and TCDF have decreased since 2002, albeit at rates of change less than 10 percent per year (i.e., first order rate coefficients greater than -0.1 yr^{-1}). This is consistent with the ROD which states that concentrations will decrease over time due to active remediation and natural recovery (EPA 2017). Since remedial action has not yet occurred, these small decreases shown in **Figure 3** are due to natural recovery alone. With these rates of change less than 10% per year, natural recovery alone is insufficient to reduce concentrations substantially and active sediment remediation is needed to achieve CULs.

Additionally, as laid out in the ROD, fish tissue concentrations in the Site are assessed at smaller spatial scales of 0.5 to 1-river mile separating the east and west sides of the river (EPA 2017). These small spatial scales were developed as part of the risk assessments in the RI based on the home ranges of the resident smallmouth bass and the human health exposure scenarios (EPA 2016). When looking at the Site as a whole, average concentrations are lower due to relatively clean samples being interspersed with those of higher concentration. At smaller spatial scales, the high concentrations carry more weight and the resulting averages are higher.

As discussed above, the 2002, 2007, and 2012 studies have limited spatial distribution of samples collected or a limited number of COCs analyzed which limit the ability to understand long-term trends at the 0.5 to 1-river mile spatial scale. Future sampling events that repeat the 2018 PDI will be used to assess the rate of decrease of COCs in fish tissue as part of the long-term monitoring program laid out in the ROD. However, with the data currently available, it is possible to estimate the rate of change at larger spatial scales than the risk-based ones in the ROD. The Pre-RD Group has proposed that the Site can be divided into 2 to 3-river mile long segments separated east and west by the river center (Geosyntec 2017). These spatial scales are not included in the ROD and have not been substantiated by EPA.

The **Supplemental Data Figures** includes a map showing the Pre-RD Group's proposed spatial scales, a table detailing the number of sample results in each segment, and plots showing the rates of change for PCBs, DDx, and the five dioxins/furans with fish tissue CULs. These results confirm that there is much more variability at smaller spatial scales and that fish tissue COCs showing Site-wide decreases since 2002 have not decreased in areas with collocated sediment contamination. For example, Segment 2W has elevated levels of PCBs, DDx, and the five dioxins/furans in sediment and shows no decrease in fish tissue concentrations for these COCs.

Summary and Conclusions

Average fish tissue concentrations from the 2018 PDI are above CULs in the Site, Downtown Reach, and Upriver Reach for PCBs, DDx, and dioxins/furans. Additionally, the concentrations in the Site are not equivalent with those in the Upriver Reach and there has been only a limited decrease due to natural recovery since 2002. These analyses suggest that active sediment remediation in the Site is required to achieve fish tissue CULs.

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cc: Davis Zhen
Hunter Young
Eva DeMaria
Josie Clark
Cami Grandinetti
Karl Gustavson

DELIBERATIVE-DRAFT Memorandum

To: Sean Sheldrake, United States Environmental Protection Agency Region 10

From: CDM Smith

Date: May 10, 2019

Subject: Background Porewater Evaluations

Introduction

Porewater is the water between and surrounding grains of sediment in the bed of a water body. In tidally-influenced water bodies like the lower Willamette River, it is usually a combination of groundwater and surface water due to the interaction between the two zones. The 2018 Pre-Design Investigation (PDI) focused it's porewater sampling on dissolved arsenic and manganese concentrations in "background" locations in the Downtown Reach and Upriver Reach (referred to collectively as the D/U Reach). This memo presents the porewater chemistry results and discusses uncertainties in the dataset.

Study Design

The 2018 PDI porewater study used small-volume peepers where dissolved arsenic and manganese diffuses across the peeper membrane and reaches equilibrium with the liquid within the vial. The porewater field sampling plan (FSP) states that samples will be considered acceptable if 80 percent (%) to 100% of equilibrium has been achieved else a correction factor will be used to approximate the equilibrium concentrations (AECOM and Geosyntec 2018). Twenty-eight days was estimated by the Pre-RD Group to be sufficient to achieve equilibrium and was therefore selected as the deployment period.

Arsenic and manganese are sensitive to the presence and amount of oxygen – when oxygen is absent, more arsenic and manganese will be dissolved in water rather than in their solid form. Nine porewater sampling locations were selected in the D/U Reach that targeted areas where dissolved arsenic and manganese concentrations would be highest and sediment concentrations were near regional background (DEQ 2013). This included areas low in oxygen, high in organic carbon, near wetlands, and near areas with historic presence of methane bubbles. These selection criteria targeted sampling locations that would be biased high and not representative of unbiased background concentrations. The nine porewater sampling locations in the D/U Reach are shown on **Figure 1**.

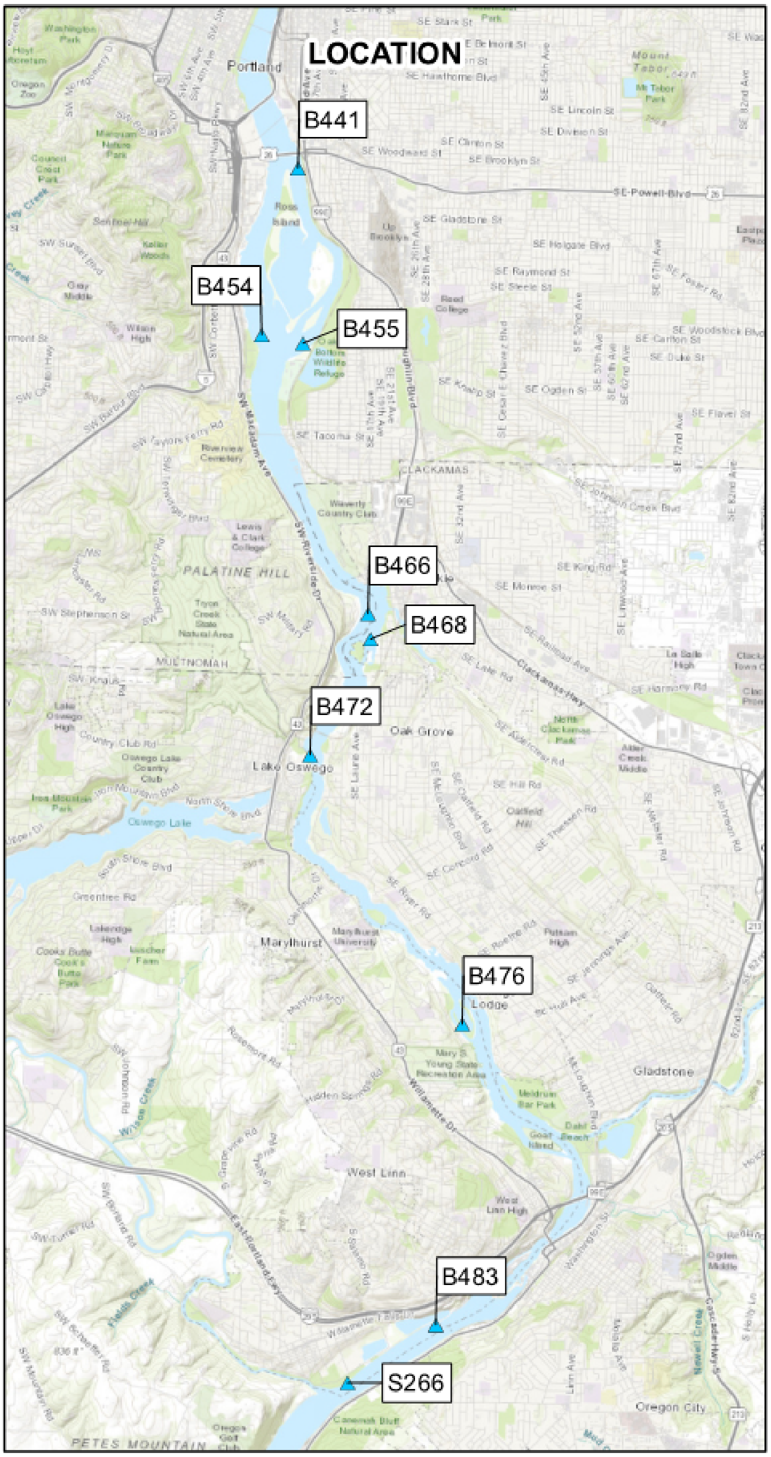

Figure 1. Targeted porewater sampling locations (n = 9) in the D/U Reach. Each porewater sampling location was collocated with a surface sediment grab sample.

Porewater Chemistry Results and Data Uncertainties

The measured concentrations of arsenic and manganese were detected above the Record of Decision (ROD) Table 17 groundwater cleanup levels (CULs) at all locations. The arsenic CUL is regulatory-based (United States Clean Water Act) while the manganese CUL is risk-based from EPA's regional screening levels (EPA 2017, 2016). Both CULs are based on human health criteria. None of the porewater samples achieved the 80% equilibrium threshold during the 28-day deployment, ranging from 40% to 66% equilibrium. Therefore, in accordance with the FSP, a correction factor must be applied to approximate equilibrium concentrations. The correction factor for arsenic was not provided in the FSP or the primary literature cited in the FSP. Therefore, corrected concentrations for arsenic have not been calculated at this time. **Table 1** summarizes the range of concentrations (measured and estimated corrected) for arsenic and manganese, respectively.

Table 1. Summary statistics for the measured and corrected estimated concentrations of arsenic and manganese in D/U Reach porewater.

Contaminant	Cleanup Level (µg/L)	Measured Concentrations		Estimated Corrected Concentrations	
		Range (µg/L)	Mean ± SD (µg/L)	Range (µg/L)	Mean ± SD (µg/L)
Arsenic	0.018	4.9 – 12	8.54 ± 2.32	NC	NC
Manganese	430	760 – 5100	2578 ± 1783	3,047 – 22,526	11,298 ± 7,111

Notes:

- µg/L = micrograms per liter
- NC = not calculated
- SD = standard deviation

The estimated equilibrium concentrations (using a correction factor) will be higher than the measured concentrations due to equilibrium not being achieved during the deployment period. However, the calculated equilibrium concentrations have an unknown amount of uncertainty and represent estimates rather than actual concentrations. Additionally, the correction factor for manganese has not been validated by EPA and the one for arsenic has not been provided at this time. Therefore, it is not possible to assess its validity nor calculate corrected arsenic concentrations.

Summary and Conclusions

All the porewater samples (measured and estimated corrected concentrations) were above CULs for arsenic and manganese. However, none of the samples achieved equilibrium and the use of a correction factor to estimate equilibrium concentrations introduces additional uncertainty to the results. Furthermore, due to the targeted nature of the sampling locations, the 2018 PDI porewater data are not representative of unbiased background conditions and the results do not supplant the regulatory- and risk-based CULs for arsenic and manganese, respectively. Rather, these data will be useful during remedial design and remedial action to understand the range of porewater concentrations that could be expected in wetlands and other reducing environments for these two contaminants.

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cc: Davis Zhen
Hunter Young
Eva DeMaria
Josie Clark
Karl Gustavson
Cami Grandinetti

DELIBERATIVE-DRAFT Memorandum

To: *Sean Sheldrake, United States Environmental Protection Agency Region 10*

From: *CDM Smith*

Date: *May 22, 2019*

Subject: *Fish Tracking Evaluations*

Introduction

At the Portland Harbor Superfund Site (Site), subsistence, recreational, and tribal fishers catch and consume different species of both resident (e.g., smallmouth bass) and non-resident (e.g., salmon) fish. Resident predator fish, such as smallmouth bass, present the greatest exposure risk to the Site contaminants of concern (COCs) due to their small home ranges and higher trophic level (EPA 2016). The Pre-Design Investigation (PDI) acoustic fish tracking study provides an update on previous research and will be used to better understand the life history of smallmouth bass in the Site. The purpose of this memo is to summarize the development of the exposure units in the Site human health risk assessment (HHRA) and evaluate the first 9 months of acoustic fish tracking data collected by the Pre-RD Group.

Smallmouth Bass Home Ranges and Risk Assessment Exposure Units

Previous studies on the home ranges, movement, and diet of resident fish in the lower Willamette River were conducted by the Oregon Department of Fish and Wildlife (ODFW) from 2000 to 2003 (Pribyl et al. 2004). These studies found that smallmouth bass preferred nearshore environments and moved more from their release location in the first month (median = 1.5 miles) relative to the rest of the study period (median = 0.25 miles). They also take spawning migrations, winter in offshore areas of deeper water, and typically aren't feeding during these time periods. Research has shown that bioaccumulation in fish tissue is associated with dietary uptake of contaminated food particles and aqueous uptake of dissolved contaminants (Streit 1988). Most of the Site risk associated with human consumption of fish is due to PCBs and dioxins/furans, which are organic compounds that do not readily dissolve in water and therefore bioaccumulate primarily from dietary uptake (EPA 2016; ATSDR 2019). As smallmouth bass predominantly feed and spend their time in small nearshore home ranges, their greatest exposure to contaminants occurs in these locations and at this spatial scale.

Based on these results, the Site HHRA assumed a 1-river mile home range for smallmouth bass and evaluated resident fish consumption risk at 1-mile and Site-wide scales with different fishing rates to account for a multi-species diet and variability in fishing behavior (EPA 2016). Smallmouth bass were used as a surrogate for the other resident fish species (common carp, brown bullhead, and black crappie) in the 1-mile exposure unit evaluation as this was the only species where samples were composited on a 1-mile scale. Additionally, the other resident fish species are estimated to have larger home ranges and are less specifically associated with small-scale feeding stations. However, the tissue concentrations vary between species with common carp having PCB concentrations an order of magnitude higher than smallmouth bass. Due to these assumptions, an uncertainty analysis was performed as part of the HHRA and concluded that the use of the 1-mile exposure unit for smallmouth bass and the multi-species diet would neither over- or under-estimate risk and should be protective of human health (EPA 2016).

Additionally, direct contact with in-water sediment is a potentially complete pathway for fishers and was assessed at 0.5-mile and Site-wide scales. The HHRA found that human health risks vary spatially throughout the Site with the highest risks at small scales in areas of elevated sediment and fish tissue COC concentrations. Therefore, the human health risk-based sediment cleanup levels (CULs) and fish tissue target levels selected in the Site Record of Decision (ROD) are based on the exposure risks at the 0.5-mile, 1-mile, and/or Site-wide scales and represent concentrations that ought to be protective for all potentially-exposed people (EPA 2017).

Acoustic Fish Tracking Study Design

The PDI acoustic fish tracking study was conducted over a 12-month period from May 2018 to May 2019. It was designed to track the presence and locations of forty smallmouth bass throughout the Site using acoustic receivers and implanted acoustic tags. The receivers were deployed to provide estimated locations of the tagged fish in three target areas of the Site: Willamette Cove (river mile [RM] 6.5E), Swan Island Lagoon (SIL; RM 8E), and RM 11.5E. This was done by deploying four or five acoustic receivers in a high-resolution array that would have the ability to triangulate a fish's location in the river and calculate an estimate of its location. Throughout the remainder of the Site, a series of eight gates were deployed downstream (RM 1.9 and Multnomah Channel), upstream (RM 11.8), and at 1-river mile intervals in the middle (RM 5, 6, 7, 8, and 9). These gates can detect when a tagged fish swims by and provide a general river mile location of the fish at a point in time but are unable to estimate its actual location.

Detection data at a gate or array was continuously recorded during the 12-month study period as tagged fish were within range, and the data were downloaded after 3, 6, 9, and 12 months. This differs from the previous fish tracking studies conducted in 2000 to 2003 which relied on opportunistic tracking during one to ten days per month. However, due to the fixed locations of the receivers (compared with the active telemetry tracking performed during the previous studies) and the receivers' detection range limitations, tagged fish could not be detected at distances greater than 1,300 feet in quiescent areas like Willamette Cove or 800 feet in noisier areas like RM 11.5E (AECOM and Geosyntec 2018). This led to gaps in the detection histories of individual fish despite the continual tracking by the acoustic receivers.

Alternatively, the receiver gates at RM 6 and 7, RM 8 and 9, and RM 11.8 are potentially within range of the arrays at Willamette Cove, SIL, and RM 11.5E, respectively. This leads to fish being simultaneously detected at a gate and an array but is not necessarily indicative of fish movement between these locations. A future evaluation not covered in this memo would be to define the uncertainty bounds of the receivers (i.e., range finding). This would allow for a more reliable interpretation of detection history when a fish is being simultaneously detected by gate(s) and array(s) but not positioned. The locations of the acoustic receivers are shown on **Figure 1**.

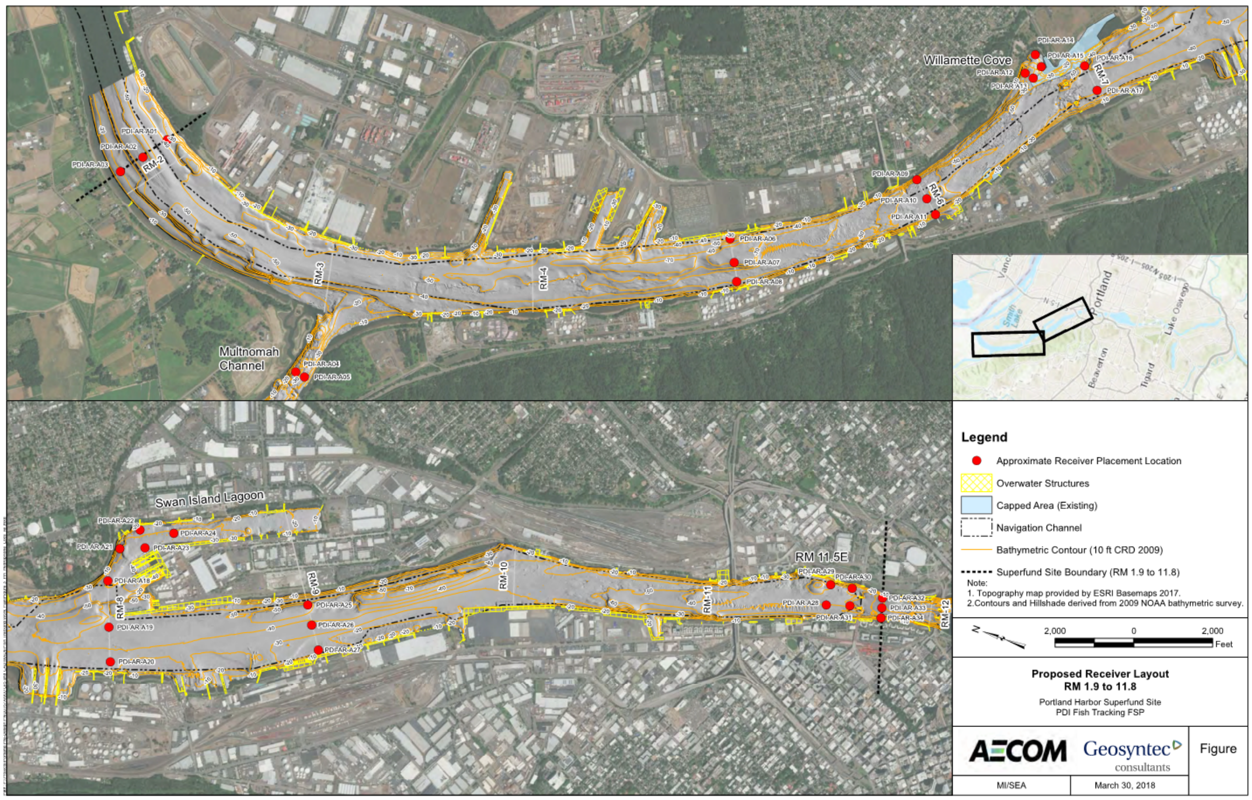

Figure 1. Deployed locations of the acoustic fish tracking receivers in the Site shown as red dots. The high-resolution arrays were positioned at Willamette Cove (RM 6.5E), SIL (RM 8E), and RM 11.5E.

Smallmouth Bass Movement Evaluations

Data were downloaded from the receivers at 3-, 6-, 9-, and 12-months during the study period with fewer fish than the original forty detected at each subsequent download event due to fish mortality, fish leaving the study area, or fish within the study area but outside of the receivers' range (i.e., head of SIL; between MC and RM 5; between RM 9 and RM 11.5E array). As no active telemetry occurred during this study, it is not possible to know the locations of the fish that were not detected by one or more receivers resulting in data gaps in the movement history. **Table 1** summarizes fish detections and available data throughout the study period.

Table 1. Number of fish detected during the fish tracking study data periods.

Fish Tracking Study Data Period	Number of Fish Detected
0 to 3 Months	40
3 to 6 Months	27
6 to 9 Months	25
9-Month Data Download Event (Jan 14 to 18, 2019)	12

Note: Data from the 12-month data download event (May 6 to 9, 2019) have not been provided to EPA.

Based on their movement characteristics, the forty smallmouth bass detected at the beginning of the study were grouped into three qualitative movement categories. Due to the limitations of the dataset, these categories represent broad patterns of movement and are not meant to be statistically rigorous. Rather, they provide a general classification for movement within the study area. These categories and the number of fish in each are summarized in **Table 2**.

Table 2. Smallmouth bass qualitative movement categories.

Qualitative Movement Category	Number of Fish
Predominantly Stationary (S)	20
Stationary with Traveling and/or Leaving Study Area (S&T/L)	16
Predominantly Traveling and/or Leaving Study Area (T/L)	4

Most of the tagged fish can be classified as predominantly stationary (n = 20); these fish do not leave their release location of Willamette Cove (RM 6.5E), SIL (RM 8E), or RM 11.5E. Sixteen of the fish exhibited movement behavior with extended periods of little movement to short duration long-distance movement episodes. Of the sixteen fish that had some movement, thirteen spent two months or greater during the summer (post-spawning) in the same general location, likely its feeding station during this period. One of the remaining three fish in this category may be in the head of SIL while the other two left the study area either downstream or upstream. This is consistent with the movement behavior measured by ODFW from 2000 to 2003 (Pribyl et al. 2004). Four fish exhibited long-distance movement episodes and/or left the study area shortly after being released. Approximately one month of data or less are available to draw conclusions about these fish. Of these four fish, two were released in the RM 11.5E array and may have been located not far upstream but out of range of the gate at RM 11.8. Daily detection summary plots (gates and arrays) and estimated fish location maps (arrays only) are provided in the **Supplemental Data Figures**.

It is important to note that there are potential aberrations in the dataset. These include the following:

- Fish detections at gate(s)/array(s) without prior detection at the adjacent upstream or downstream gate/array
- Estimated coordinate locations that appear on land an unreasonable distance from the river bank

These aberrations don't appear to have major consequences on the quality or integrity of the data but suggest that some fish detections and coordinate locations should be interpreted as estimates. Additionally, active telemetry did not occur during this study to attempt to locate undetected fish or validate the fish movement being detected by the deployed receivers. To EPA's knowledge, only one fish was inadvertently caught during the fish tracking study. This fish was euthanized during the PDI fish tissue sampling before being properly identified. Until its incidental catch in August 2018, this fish was in Willamette Cove and classified as predominantly stationary for these evaluations.

Summary and Conclusions

Of the forty fish investigated during the fish tracking study, 50% exhibited little movement within or outside of their release area, while an additional 35% spent two months or greater during the summer and fall (post-spawning) in the same general location after moving from their initial release point. Two fish (5%) that left the study area were initially released at the RM 11.5E array and may have been located just upstream of the RM 11.8 gate. These results suggest that up to 90% of the tagged smallmouth bass spent most of their feeding time in the same relatively small area, consistent with the findings of Pribyl et al. (2004). Therefore, the 2018 acoustic fish tracking study reinforces the home range estimates from the previous ODFW study and provides additional justification for the 0.5- and 1-mile exposure units in the ROD.

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cc: Davis Zhen
Hunter Young
Eva DeMaria
Josie Clark
Karl Gustavson
Cami Grandinetti